Final

Feasibility Study for the Restoration of Ridinger Lake

Submitted To:

Ridinger Lake Homeowners Association, Kosciusko Co.
RR3, Box 295
Pierceton, Indiana 46562

Submitted By:

International Science & Technology, Inc.
P.O. Box 349
10501 Hague Road
Fishers, Indiana 46038

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EXECUTIVE SUMMARY

International Science & Technology, Inc. (IS&T) has provided technical services to the Ridinger Lake Homeowners Association in conducting a feasibility study of the restoration of Ridinger Lake. The glacially-formed water body, located in Kosciusko County, Indiana, has experienced a marked deterioration in water quality due to nutrient enrichment. Additionally, sediment accumulation at the mouths of both major tributaries to the lake has impaired navigation and contributed to the increasing macrophyte coverage. In 1986, the Indiana Department of Environmental Management (IDEM) placed Ridinger Lake in its Class Three category of lakes. Lakes in this category are in an advanced state of eutrophication and commonly produce nuisance algal blooms during the summer months.

The objectives of the feasibility study, funded through the Indiana Lake Enhancement Program (LEP) were to:

- Assess the current condition of the lake system and establish a baseline against which future changes can be measured.
- Identify potential threats to the well-being of the system, both in the lake and in the watershed.
- Develop mitigative strategies that have the greatest probability of success in improving the overall quality of the lake.

In pursuit of these goals, IS&T implemented a four part program. First, all relevant background information (e.g., resource maps, soil manuals, fisheries studies) was gathered and reviewed to understand the physical setting and to assess the availability of previous research. Second, a lake survey was conducted to collect data on water quality, sediment quality, phytoplankton abundance, and aquatic macrophyte distribution. Third, a watershed survey was completed to identify upland activities resulting in excessive soil erosion and sediment/nutrient transport to the lake. Finally, a program for implementing mitigative strategies was developed to address the identified problems. Part of this program included long-term lake and tributary monitoring to evaluate water quality trends and address potential impacts before they impair use of the valuable Ridinger Lake resource.

Based on the results of the watershed analysis, lake and tributary sampling, and visual observations, the primary source of sediment and nutrient loading to Ridinger Lake was identified as the Elder Ditch drainage basin. Specific problem areas within this drainage basin are located within the Troy-Cedar Branch sub-basin. No single point sources of contamination were identified however. Ridinger Lake is impacted by non-point source pollution (i.e., diffuse inputs of nutrients and sediments). As such, increased eutrophication of the lake cannot be tied to specific causal agents or sources within the watershed.

The results of the in-lake and watershed study indicate that Ridinger Lake is experiencing moderate sedimentation and eutrophication. The primary thrust of management efforts should be directed at controlling sediment and nutrient production in the watershed. Limiting the input of these parameters offers the most promising avenue for maintaining the quality of the resource. A general, integrated program for managing Ridinger Lake should include application of: (1) appropriate best management practices (BMPs) in the watershed, especially near stream corridors and at animal waste facilities; (2) effective waste water treatment and septic system maintenance at lake shore residences; and (3) efective runoff management at the Jellystone Park Campground facilities. In-lake restoration procedures (e.g., sediment removal, macrophyte harvesting, and artificial lake circulation) are available management tools to control sedimentation and effect immediate improvement in water quality. In-lake procedures are recommended, however changes as a result of these procedures will be short-lived without widespread implementation of watershed best management practices. The Ridinger Lake Homeowners Association, and other residents in the watershed, should become familiar with agricultural BMP's for controlling sediment and nutrient export to surface waters. The Association should work with the SCS District Conservationists's office to encourage the implementation of BMPs, especially in the critical areas identified in this report. SCS is the agency that is responsible for coordinating BMP applications and will provide free advice to landowners on appropriate strategies and designs.

In light of a five year SCS study begun in the spring of 1990 that is designed to accelerate BMP application in the northern Tippecanoe River basin, including the Ridinger Lake watershed, a Lake Enhancement Program Design Study is not recommended at this time. While more in-depth monitoring and further evaluation of control strategies would be beneficial, costs associated with the additional monitoring would not be warranted. The information contained in this report will be utilized by the SCS study to target BMPs, further decreasing the amount of time required before watershed controls effect improvements in water quality. The Ridinger Lake Homeowners Association has, with this report, sufficient information to develop detailed requests from qualified contractors for in-lake restoration measures. Kosciusko County and the Lake Enhancement Program office should be consulted regarding financial support for in-lake restoration.

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SECTION 1. INTRODUCTION

This report presents the results of a Feasibility Study conducted on Ridinger Lake by International Science & Technology, Inc. (IS&T) for the Ridinger Lake Homeowners Association. The project was performed and funded under the provisions of the State of Indiana "T by 2000" Lake Enhancement Program (LEP). The LEP was established to ensure the continued viability of Indiana's lakes by controlling sediment related problems, primarily erosion and nutrient enrichment. The objectives of Feasibility studies conducted under this program are to characterize the lake and surrounding watershed, identify water quality related problems, present alternative solutions, and recommend the most appropriate solutions. The ultimate objective of the program is to restore the well being of the lakes through development of specific plans of action for restoration (Design Phase) and, when appropriate, installation of the required control measures (Construction Phase).

1.1 RIDINGER LAKE

Ridinger Lake is located in Kosciusko County, IN, approximately 20 miles northeast of the city of Warsaw (Figure 1). The lake has a surface area of 136 acres, a maximum depth of 42 feet and a mean depth of 21 feet (IDEM, 1986). The lake bottom consists of sand, muck and clay (IDNR, 1978). Residential development on the lake is concentrated along the east and southwest shores. Data collected in 1980 documented 116 permanent residences on Ridinger Lake (Hippensteel, 1989). On the west shore of the lake is a family campground, Yogi Bear's Jellystone Park. This park has a capacity of 1200 campsites. Typically, 25% to 30% of the sites are filled at any one time, with the exception of holidays, when the park is filled to capacity (pers. comm., Yogi Bear's Jellystone Park).

The 21,487 acre watershed is predominantly agricultural. Corn, soybeans and wheat are the principal crops; and poultry, hogs, and cattle are the primary livestock raised. Approximately 60% of the watershed lies in Kosciusko County and the remainder is in Whitley County. The major tributaries to the lake are Shanton/Elder Ditch, entering from the south, and an unnamed tributary entering from the northeast. An intermittent tributary enters the lake on the eastern side. The Shanton/Elder ditch system drains the farthest reaches of the watershed and includes several smaller lakes, including Robinson and Troy Cedar. Figure 2 shows the drainage basin and tributary streams visible on a 1:24,000 scale topographic map. Ridinger Lake discharges into the Barbee Lake Chain via Grassy Creek, which flows from the northwest corner of the lake to Big Barbee Lake.

Geologically, the Ridinger Lake watershed is composed of Devonian age bedrock materials; largely limestone, dolomite, and black shale. Unconsolidated deposits consist of glacial till in hummocky moraine form. The glacially formed lake was a result of the advance and retreat of the Saginaw and Erie lobes of the main glacier extending southwest from the Lake Erie and Saginaw Bay Basins during the most recent period of glaciation (14,000-22,000 years ago) (Clark, 1980). The moraine topography with

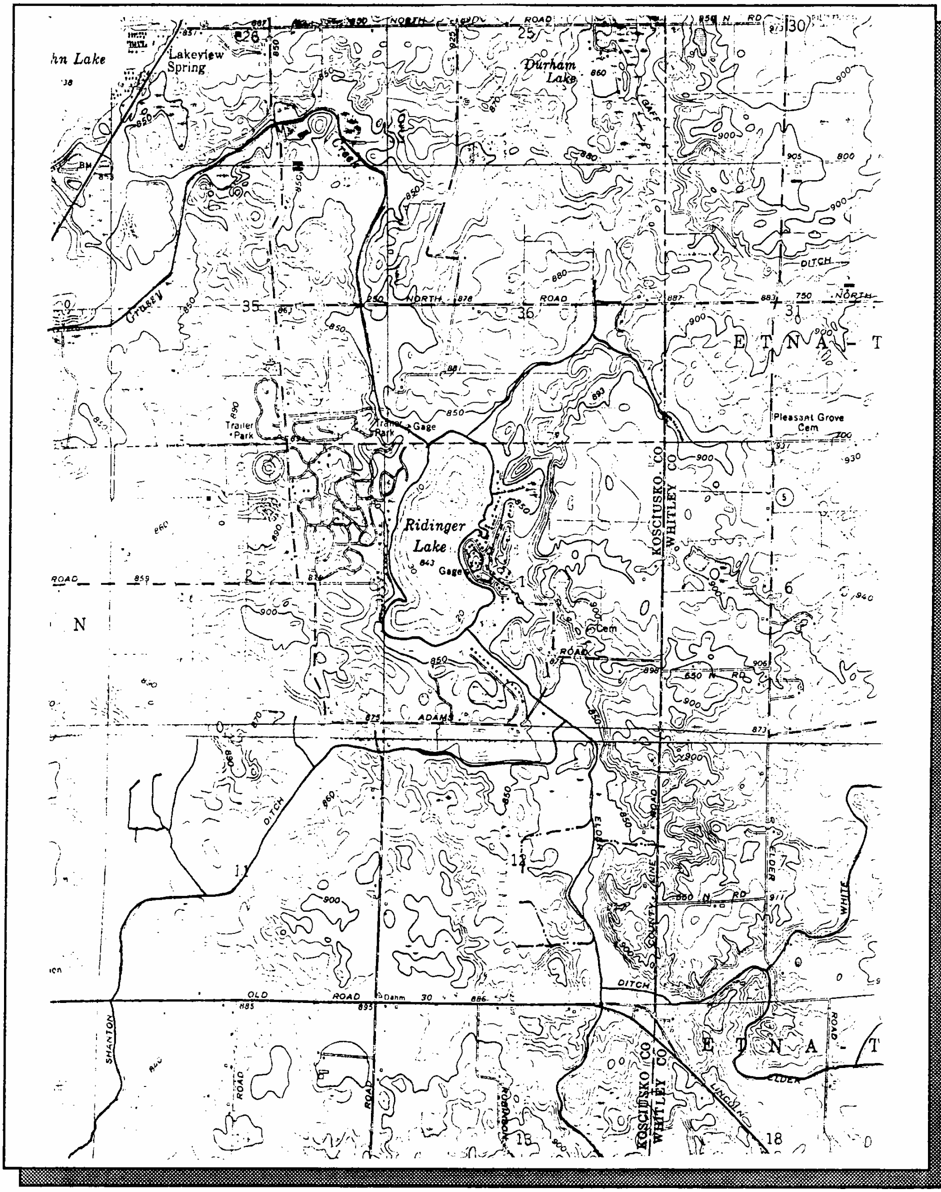


FIGURE 1. Portions of the USGS North Webster and Pierceton, Indiana quadrangles showing the location of Ridinger Lake.

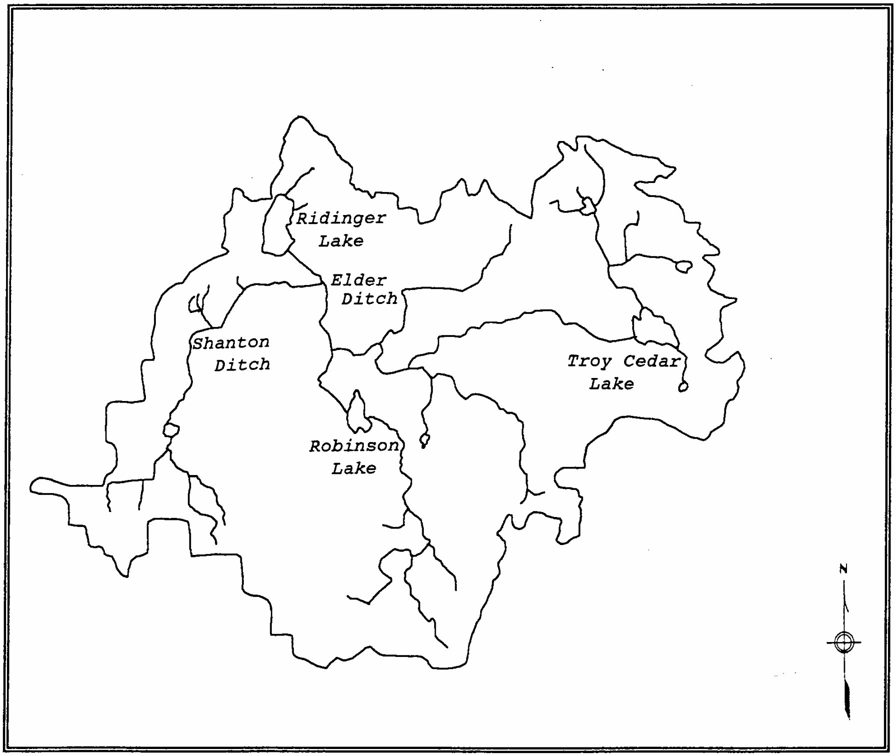


FIGURE 2. Ridinger Lake watershed and major tributary systems. (Scale 1 : 68,273)

interspersed lakes, bogs, and glacial drainage troughs and plains is evidence of the glacier's effect on north-central Indiana.

Soils surrounding Ridinger Lake have been described by the Soil Conservation Service (SCS) as ranging from nearly level to steep and well drained. The two major soil associations found in this area are the Riddles-Wawasee and the Riddles-Ormas-Kosciusko Associations.

Riddles-Wawasee Association soils are found primarily in the eastern portion of the watershed. This association is characterized by level to strongly sloping topography, with knobs, broad ridges, and narrow depressions, and moderately well defined surface drainage.

The Riddles-Ormas-Kosciusko Association predominates in the western portion of the drainage basin. This association is also characterized by nearly level to steep land slopes, but with prominent ridges and deep depressions as dominant land features. Surface drainage is moderately defined, with lakes and marshes found in the lower parts of the landscape.

1.2 NATURE OF THE PROBLEM

Deteriorating water quality in the lake has been a growing concern since 1975, when the lake was surveyed by the Indiana State Board of Health (ISBH). Based on the results of that survey, the Indiana Department of Environmental Management (IDEM) placed Ridinger Lake in Trophic Class Three, with a Eutrophication Index (EI) value of 58 (IDEM, 1986). However, a recent re-evaluation of the original data gives the lake a EI value of 63, but does not change the Trophic Class of the lake (Harold BonHomme, pers. comm.). With the exception of Yellow Creek Lake, Ridinger Lake has the highest EI value of all lakes classified by IDEM in Kosciusko County. Lakes in Trophic Class Three are in an advanced state of eutrophication, and commonly produce nuisance algal blooms during the summer months. Other characteristics include high water column and tributary nutrient concentrations, oxygen depletion below the thermocline in mid- to late-summer and under ice-cover, and low water clarity.

In an investigation of Kosciusko County lakes in 1988, Hippensteel (1989) found that Ridinger Lake had the lowest Secchi disk depth and highest total phosphorus (TP) concentration of any lake sampled in the Barbee Lake Chain. TP concentration was 0.55 mg/L, an increase of 0.50 mg/L over the concentration reported in 1975. The deterioration in quality and condition has been especially noticeable during the past decade (pers. comm., Ridinger Lake Homeowner's Association). Two fish kills were documented during this period, as well as an increase in macrophyte density. Mats of filamentous algae are commonly found interspersed throughout the macrophyte beds.

In addition to nutrient enrichment, sedimentation is also of concern. Sand bars can be seen near the mouths of both major tributaries to the lake. The sandbars have impaired navigation at these locations, and have contributed to the increasing macrophyte coverage in the lake.

1.3 STUDY OBJECTIVES

The objective of the Ridinger Lake Feasibility Study was to assess the current conditions in the lake and watershed with respect to sedimentation and water quality, and develop mitigation strategies that would have the greatest probability of success in improving the overall quality of the lake.

Four phases of activity were required to meet the project objective. First, relevant information on the lake and watershed (e.g., USGS topographic maps, aerial photographs of the lake and watershed, soils and geological information, fisheries studies, hydrological data, and previous water quality studies) was collected and reviewed. This information was used to understand the physical setting of the lake, and the current status of knowledge regarding sedimentation and water quality problems.

The second phase of the study involved collection of field data. Water samples and in-situ chemical and physical data were collected from the lake and tributaries. Sediment characteristics, algal and aquatic macrophyte composition, and bathymetric data also were collected. These data provided the most recent evaluation of chemical, biological and physical conditions in the lake.

A survey of the watershed was the third phase of the project. Areas of excessive nutrient and sediment loading were identified using the Agricultural Non-Point Source Pollution (AGNPS) computer simulation developed by the U.S. Department of Agriculture. The watershed survey was critical in addressing problems at their source, and for developing the most appropriate mitigative strategies.

The final phase of the project was to develop recommendations to mitigate the problems observed in this study and in prior studies. The methods used in each phase of the project and the results of the study are presented in the sections that follow.

SECTION 2. HISTORICAL DATA

The following section describes the historical data collected for this study. This information included water quality data, fisheries surveys, aquatic plant surveys, soils data, land use, and hydrological data. Several state and county agencies, as well as universities, were contacted in pursuit of this information. In addition to published reports and studies, the Ridinger Lake Homeowner's Association provided observations on the condition of the lake and its tributaries. Table 1 presents a summary of the historical data obtained for Ridinger Lake.

2.1 WATER QUALITY

Table 2 presents a summary of water quality data collected on Ridinger Lake, and its major tributaries, by the Indiana Department of Natural Resources (IDNR), IDEM, ISBH, Tri-State University and the Kosciusko County Health Department. Although there is little consistency among the parameters reported, an increase in TP concentration is apparent in both the lake and Elder Ditch. In 1975, the ISBH reported a TP concentration in the Elder Ditch in-flow of 0.08 mg/L. In the same vicinity, Hippensteel (1989) found a concentration of 0.26 mg/L, an increase of 225% over the 1975 data. An even larger increase in TP was seen in the lake itself. ISBH data show a value of 0.05 mg/L for a mid-lake sample collected during July of 1975. Hippensteel (1989) found a TP concentration in a mid-lake sample of 0.55 mg/L, an increase of 1,000% over the 1975 data.

The permanent dwellings on the lake all utilize septic systems for treatment of sewage and wastewater. The possibility of septic field leachate reaching Ridinger Lake was investigated by the Kosciusko County Health Department in August of 1987. A septic system survey was conducted along the west shore of the lake, excluding Yogi Bear's Jellystone Park campground. Dye testing was conducted at eight of the 116 permanent dwellings on the lake. Of these, two exhibited positive dye test results.

The Jellystone Park Campground operates their own sewage treatment facility. This consists of a contact stabilization plant followed by chlorination facilities and rapid sand filters. The plant has a design capacity of 76,000 gallons per day. The discharge site is identified in the facility's National Pollutant Discharge Elimination System (NPDES) permit as Elder Ditch. There are no phosphorus limitations for the treatment plant discharge. Hippensteel (1989) concluded that phosphorus loading from this system did not appear to be significant. Monthly operations reports submitted to IDEM and reviewed by IS&T, as well as a treatment plant inspection report dated August 1989 show no violations of the NPDES permit regulations. The average daily discharge for the plant between June 1988 and June 1989 was 9,000 gallons per day.

TABLE 1. Historical data summary.

DATE	AGENCY	DESCRIPTION
1943-52	USGS	Lake discharge measurements (cfs)
1950	USGS	Lake gage height vs. discharge curve
1975	ISBH	Lake Survey Data
1978	IDNR	Fish Management Report
1981	IDNR	Weed Control Permit
1981	IDNR	Fisheries Deterioration Report
1982	ISBH	NPDES Permit application - Wastewater Treatment Plant at Jellystone Park
1982	IDNR	Fish Management Report
1982	Kosciusko Co. Health Dept.	Bacteriological Examination of Bathing Beach Water
1983	IDNR	Fish Population Recovery Report
1985	IDNR	Weed Control Permit
1987	Kosciusko Co. Health Dept.	Septic System Survey
1988-89	IDEM	Wastewater Treatment Plant Operation Reports
1989	Kosciusko Co. Health Dept.	Wastewater Treatment Plant Inspection Report
1989	DNR	Correspondence from Jellystone Park Camp
1989	Tri-State University	Highly Erodible Soils Maps
1989	Tri-State University	Preliminary Investigation of the Lakes of Kosciusko County
1989	SCS	Soil Survey of Kosciusko County, Indiana

TABLE 2. Ridinger Lake historic water quality data.

DATE	LOCATION	SOURCE	TP mg/L	OP mg/L	NO3 mg/L	NH4 mg/L	TKN mg/L	FECAL COLIFORM #/100 ml	D.O. mg/L	SECCHI ft.
July 1975	mid-lake	ISBH	0.05	0.03	2.0	0.4	1.1		12.0	3.5
July 1978	mid-lake	IDNR							8.0	2.5
July 1982	Jellystone Park Beach	Kosciusko Co.						<10/100 ml		
1988	mid-lake	Tri-State Univ.	0.55							4.0
July 1975	Elder Ditch	ISBH	0.08	0.05	0.8	0.1	0.7			
July 1982	Elder Ditch	Kosciusko Co.						10/100 ml		
1988	Elder Ditch	Tri-State Univ.	0.26							
July 1975	North inlet	ISBH	0.09	0.08	8.0	0.1	0.8			
July 1982	North inlet	Kosciusko Co.						<10/100 ml		
July 1975	Outlet	ISBH	0.57	0.01	1.4	0.1	1.4			
July 1982	Outlet	Kosciusko Co.						<10/100 ml		

2.2 FISH POPULATION SURVEYS

Fish population surveys of Ridinger Lake were conducted in 1978, 1981, 1982 and 1983 by IDNR. Species documented in these survey reports, and their relative abundance, are listed in Table 3. The 1978 survey also included water quality measurements and a list of common species of aquatic plants found in Ridinger Lake at the time of the survey. The 1978 survey concluded that the lake contained a satisfactory warm-water fishery, and recommended no further management actions. In June 1981, Ridinger Lake was among 10 Indiana lakes to experience fish kills. The 1981 IDNR report concluded that heavy rains during the month of June (4.5 inches above normal) and the resulting turbidity, combined with spawning-induced stress, were the most likely contributors to the Ridinger Lake fish kill. The results of the 1981 fisheries survey showed that all game fish species, except bass and catfish, had been severely reduced. The report

TABLE 3. Fish species and relative abundance in Ridinger Lake.

COMMON NAME	SCIENTIFIC NAME	1978	1982	1983
Bluegill	*Lepomis macrochirus*	45.2%	17.3%	37.1%
White Crappie	*Pomoxis annularis*	10.0%	14.4%	24.4%
Black Crappie	*Pomoxis nigromaculatus*	8.8%		5.6%
Lake Chubsucker	*Erimyzon sucetta*	6.3%	2.4%	3.0%
Yellow Perch	*Perca flavescens*	5.4%	2.1%	3.2%
White Sucker	*Catastomus commersonii*	4.2%	3.7%	2.5%
Golden Shiner	*Notemigonus crysoleucus*	2.6%	10.2%	2.0%
Warmouth	*Lepomis gulosus*	2.5%		
Largemouth Bass	*Micropterus salmoides*	2.2%	22.5%	7.9%
Longear Sunfish	*Lepomis megalotis*	2.1%		
Yellow Bullhead	*Ictalurus natalis*	2.0%	3.2%	
Spotted Gar	*Lepisosteus oculatus*	1.9%	1.1%	0.2%
Brown Bullhead	*Ictalurus nebulosus*	1.9%	1.3%	
Pumpkinseed	*Lepomis gibbosus*	1.6%		
Spotted Sucker	*Minytrema melanops*	1.1%	3.1%	1.4%
Gizzard Shad	*Dorosoma cepedianum*	0.6%	15.1%	8.5%
Grass Pickerel	*Esox americanus*	0.6%		
Readear Sunfish	*Lepomis microlophus*	0.5%	0.1%	
Hybrid Sunfish	*Lepomis* spp.	0.4%		
Bowfin	*Amia calva*	0.2%		
Carp	*Cyprinus carpio*	0.1%	0.9%	0.4%
Green Sunfish	*Lepomis cyannelus*	0.1%	0.1%	
Logperch	*Percina caprodes*	0.1%		
Brook Silversides	*Labidesthes sicculus*	observed	0.6%	
Bluntnose Minnow	*Pimephales notatus*		1.3%	
Channel Catfish	*Ictalurus punctatus*		0.4%	0.6%
Quillback Carpsucker	*Carpiodes cyprinus*		0.2%	
All Sunfish Other Than Bluegill				0.5%
All Bullheads				2.1%
Other Game Fish (including White Bass & Northern Pike)				0.3%
Other Nongame Fish				0.2%

recommended total eradication of existing fish and restocking of game fish species. However, a follow up investigation in 1983 revealed that the game fish population had recovered naturally. A second fish kill was reported to have occurred in 1985 (pers. comm., Ridinger Lake Homeowners Association). IDNR has no documentation of this fish kill and no supporting data are available.

2.3 AQUATIC PLANTS

The aquatic plant survey conducted by IDNR during the 1978 fisheries survey identified 15 plant species in Ridinger Lake. The results of this survey are presented in Table 4.

TABLE 4. Historical data on aquatic plant species in Ridinger Lake. (1978 IDNR Fish Management Report)

COMMON NAME	SCIENTIFIC NAME	COVERAGE
Bulrush	Scirpus spp.	Rare
Cattail	Typha spp.	Rare
Pickerelweed	Pontederia spp.	Common
Spatterdock	Nuphar spp.	Common
Spike Rush	Eleocharis spp.	Rare
Water Lily	Nymphaea spp.	Rare
American Pondweed	Potamogeton nodosus	Rare
Chara	Chara spp.	Common
Coontail	Ceratophyllum demersum	Abundant
Curly-leaf Pondweed	Potamogeton crispus	Common
Leafy Pondweed	Potamogeton foliosus	Rare
Milfoil	Myriophyllum spp.	Abundant
Sago Pondweed	Potamogeton pectinatus	Rare
Duckweed	Lemna spp.	Common
Filamentous algae		Common

Herbicides have been used in the past to control macrophyte growth in the Lake. In 1981, and again in 1985, IDNR issued a weed control permit to the Dalton Lawn Rangers, Inc., a Warsaw based company. The permit allowed the use of Diquat, Aquathol K and Cutrine Plus for removal of Milfoil, Coontail, Chara, Elodea and algae in Ridinger Lake. There are no other records of weed control permits issued after 1985. In April 1989, IDNR was contacted by the Jellystone Park Campground concerning a means of weed control other than chemical applications or harvesting. The correspondence from Jellystone Park indicated that neither harvesting or spraying had produced any long term success, and inquired into the use of Grass Carp for weed control. The stocking of Grass Carp is illegal in Indiana; the IDNR recommendation was to continue using chemical herbicides or to install piers and boat docks which would extend past the weed line.

2.4 ERODIBLE SOILS

Areas of highly erodible soils in the Ridinger Lake watershed were identified from reports published by the Kosciusko and Whitley County Soil and Water Conservation Districts. These reports, produced in cooperation with the SCS and other agencies, identify areas with high proportions of sheet, rill, and gully erosion. An additional source of information was a map of erodible soils in Kosciusko County prepared by Dr. Peter Hippensteel (Tri-State University, Angola, IN).

2.5 LAND USE

Historically, the majority of the land in Kosciusko County has been utilized for agriculture. Grain farming and livestock production are the major farming enterprises. According to a 1941 land use report for the county, the main crops grown were corn, soybeans and wheat. The primary livestock produced were poultry, hogs and cattle. Data obtained from the Conservation Technology Information Center (CTIC) for 1984 and 1988 showed that corn was the dominant crop, followed by soybeans and small grain crops (such as wheat, rye, barley, oats, etc.). In 1984, conservation tillage practices were utilized on 45 percent of the active cropland (CTIC, 1989). The primary type of conservation tillage practiced in 1984 was mulch-till, where the total soil surface is disturbed just prior to planting, and weed control is accomplished using a combination of herbicides and/or cultivation. At least 30 percent of the soil surface is left covered by residue after planting to reduce soil erosion by water and wind. CTIC data for 1988 indicate conservation tillage to be practiced on 49 percent of the active cropland in Kosciusko County. Once again, mulch-till was the primary type of conservation tillage, with no-till accounting for 10 percent of the conservation tillage practiced. No-till conservation tillage leaves the soil undisturbed prior to planting. Planting is done in a narrow seedbed created by a planter or drill and weed control is accomplished using herbicides.

2.6 NATURAL AREAS AND ENDANGERED OR IMPORTANT SPECIES

Significant natural areas and endangered and threatened species in the Ridinger Lake watershed were identified by the IDNR Division of Nature Preserves. The Division of Nature Preserves has a database of information pertaining to these significant areas and species and can identify their locations by USGS quadrangle map, giving latitude and longitude coordinates. Table 5 contains a listing of these species and areas identified by quadrangle.

TABLE 5. Significant natural areas and endangered/threatened species.

U.S.G.S. QUADRANGLE	NATURAL AREA	SPECIES COMMON NAME	SPECIES SCIENTIFIC NAME	STATUS	LAT.	LONG.
North Webster						
		Osprey	*Pandion haliaetus*	SE	411530	854000
		Nuttall Pondweed	*Potamogeton epihydrus*	SE	411538	854002
Pierceton						
		Foxtail Sedge	*Carex alopecoidea*	SE	411335	853851
Lorane	no significant natural areas or endangered/threatened species.					
Ormas	no significant natural areas or endangered/threatened species.					

Status: SE = endangered; ST = threatened; SR = rare; SCC = special concern;
WL = watch list; # = observed prior to 1960

SECTION 3. METHODS

This section of the report describes the methods used to complete the Ridinger Lake feasibility study. The data collection efforts for this project were divided into two sub-tasks: (1) a lake survey, and (2) a watershed survey. These subtasks are described below.

3.1 LAKE SURVEY

IS&T personnel conducted a survey of Ridinger Lake during the late summer and fall of 1989 to collect the information required for a detailed assessment of the current conditions in the lake and watershed. Samples were collected to analyze lake and tributary water quality, phytoplankton species and abundance, and sediment nutrient concentrations. Bathymetric surveys were conducted near the mouths of the three tributaries. The location and composition of emergent, floating, and submergent vegetation was determined. Land use patterns in the watershed (e.g, rowcrops, urban, etc.) were obtained using aerial photographs and confirmed by field reconnaissance. The methods used for sample collection and other components of the field survey are described below.

3.1.1 In-situ Measurements

In-situ water quality data, water samples, and phytoplankton were collected at the deepest portion of the lake (Figure 3). In-situ profile measurements of temperature, dissolved oxygen and pH were made using a Hydrolab "Surveyor II" Environmental Data System. The Hydrolab was calibrated in the laboratory prior to use in the field. A circulator assembly was used to ensure adequate water contact with the dissolved oxygen membrane. Measurements were recorded at the surface, at a depth of three feet, five feet, and at five foot increments to the lake bottom. Secchi disk transparency was measured on the shaded side of the boat. The secchi disk was lowered until it disappeared, and then raised until it reappeared. The average of these two depths was reported as Secchi disk depth. Percent light transmission was recorded at three feet using a Martek Model XMS transmissometer. This instrument was calibrated on the boat prior to use.

3.1.2 Chemical Measurements

Water samples were collected at the surface, mid-depth (20 ft.) and approximately one (1) foot above the lake bottom (37.5 ft.) using a 6-L (6.6 quart) vertical Van Dorn water sampler. All in-lake samples were collected at the same location as the in-situ data. The sample from each depth was poured directly from the Van Dorn into a clean 4-L Cubitainer container. Samples collected for fecal coliform analysis were placed in sterilized, 100 ml Whirlpak containers. All samples were immediately placed in coolers and stored at $4^{o}C$ prior to shipment to the IS&T analytical laboratory. The samples were received at the laboratory and the analyses begun within 24 hours of collection. Table 6 lists the analytes measured in the water samples, the analytical methods used, and references for these methods.

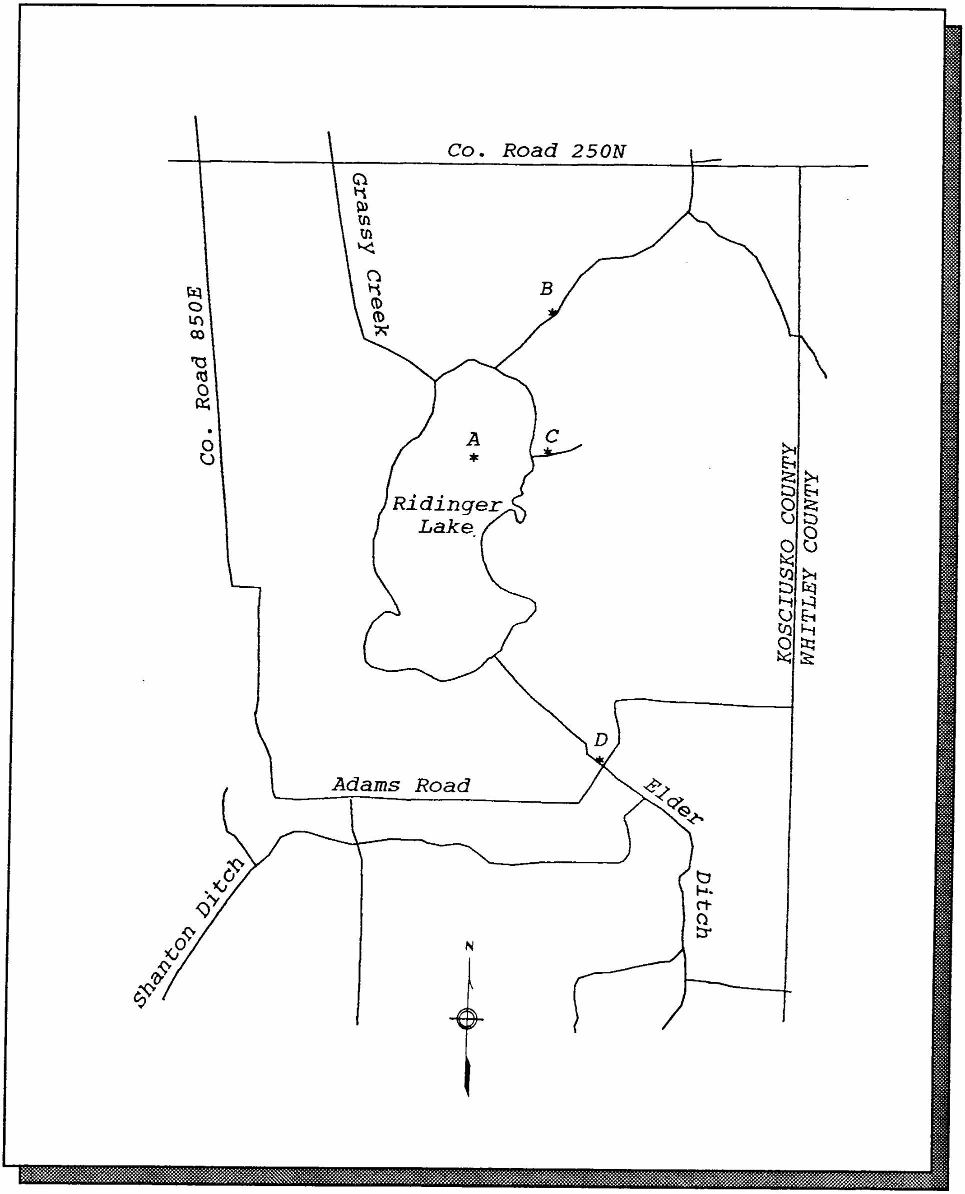


FIGURE 3. In-lake and tributary sampling locations. Site A: in-lake sampling station; Site B: Tributary #1; Site C: Tributary #2; Site D: Elder Ditch.

TABLE 6. Chemical parameters and analytical methods.

PARAMETER	INSTRUMENT OR METHOD	REFERENCE
Chlorophyll _a_ (Chla)	Spectrophotometer	Standard Methods, 16th ed.
Fecal Coliform	Incubation, visual count	Standard Methods, 16th ed.
Ammonia ($N-NH_4$)	Flow Injection Analysis	EPA 350.1
Nitrate (NO_3)	Flow Injection Analysis	EPA 383.2
Total Kjeldahl Nitrogen (TKN)	Flow Injection Analyses	EPA 351.2
Ortho Phosphorus (OP)	Flow Injection Analysis	EPA 365.1
Total Phosphorus (TP)	Flow Injection Analysis	EPA 365.1
Total Suspended Solids (TSS)	Gravimetric	EPA 160.2
Temperature	In-situ, Hydrolab Surveyor II	
Dissolved Oxygen	In-situ, Hydrolab Surveyor II	
pH	In-situ, Hydrolab Surveyor II	

In addition to the water samples, quality assurance samples were also collected in the field and included in the shipment to the analytical laboratory. These samples consisted of a blank (deionized water that was poured into the Van Dorn and then into a cubitainer) and a field duplicate sample. The blank sample was used to evaluate potential contamination due to field procedures. The duplicate sample, obtained from a second water sample collected at one of the three depths, provided a measure of variability within the water column. Laboratory split samples (a second aliquot poured from the same container) were also analyzed. These analyses provided an estimate of analytical precision.

Water quality samples were also collected from the tributaries to Ridinger Lake (i.e. Elder Ditch, Tributary #1 entering from the northeast, and Tributary #2 entering from the east) following a storm event on November 15, 1989. Figure 3 shows the location of tributary sampling stations. One grab sample was collected from each tributary by immersing a clean, rinsed and labeled 1-L Cubitainer into the stream at mid-channel. The tributary samples were placed on ice and shipped to the IS&T analytical laboratory within 24 hours of collection. Samples were analyzed for all of the parameters listed in Table 6, with the exception of fecal coliform.

3.1.3 Biological Sample Collection

NO CHANGE FROM DRAFT

Two vertical plankton tows were taken using a 80-μ mesh plankton net with an opening of one foot. The first tow was from a depth of five (5) feet to the surface. The second tow was from a depth of twenty (20) feet and included the thermocline. The plankton samples were immediately preserved with Lugol's solution and stored in labeled, opaque bottles. Phytoplankton were identified to species and enumerated using the settling chamber-inverted microscope technique described by H. Utermöhl (Sournia, 1972).

3.1.4 Sediment Sample Collection

A sediment survey was conducted in the lake and in the two major tributaries, Elder Ditch and Tributary #1. Sediment samples were collected along a transect running 100 yards upstream from each tributary mouth, to a point in the lake 100 yards from the mouth. Five sediment samples, spaced approximately 40 yards apart, were collected along each transect. In silty areas, the samples were collected as core samples using a Wildco K-B sediment core sampler. Where a hard bottom or macrophyte growth prevented the use of this corer, a Petite Ponar dredge was utilized to obtain the sediment sample. The sediment samples were placed in 250 ml containers and shipped in coolers via overnight express to the IS&T laboratory. The top three (3) inches of sediment from each sample were analyzed for TP, TKN, cadmium, chromium, lead, nickel and zinc.

As a second component of the sediment survey, sediment probings were conducted at each station on the sediment sample transect. A sediment probe was used to detect the depth to the sediment surface and to detect the probe refusal depth, or the depth to which the probe could be pushed into the sediments. This information was used to estimate the depth of recently deposited sediments.

3.1.5 Aquatic Vegetation

An aquatic plant survey of Ridinger Lake was conducted to quantify the distribution of submerged, emergent, and floating macrophytes. Plants were identified to the species level in the field. Areal coverage was sketched on a map of the lake, and later digitized into IBM-PC compatible data files. Separate maps were prepared for floating, emergent, and submergent species identified. A Manual of Aquatic Plants (Fassett, 1980) was used for identification.

3.1.6 Bathymetric Survey

A bathymetric survey was conducted at the mouth of each tributary using a recording fathometer (Lowrance "Eagle"). Survey transects ran perpendicular to the lake shore, and were created by triangulating from unique shoreline features. The latter provided reference points that allowed accurate placement of survey transects on USGS topographic maps. Care was taken to maintain constant boat speed during each transect run. Fathometer paper records were digitized and stored in IBM-PC compatible data files. A contour mapping software program ("SURFER") was used to construct bathymetric maps of the tributary mouths and associated shoals from the digitized information. Figure 4 shows the three areas of the lake that were surveyed.

The results of the bathymetric survey were compared to bathymetric data collected in 1954. Estimates of the amount of sediment deposition at the mouth of the three Ridinger Lake tributaries were made by comparing a 1954 hydrographic survey (IDNR, 1954) with the 1989 IS&T survey. Volumes of water contained in the three tributary regions were determined using the following equation (Wetzel and Likens, 1979):

$$V=\frac{h}{3}\left(A_1+A_2+\sqrt{A_1A_2}\right)$$

where:
V = volume;
h = depth of stratum;
A_1 = area of upper surface;
A_2 = area of lower surface.

Estimates of changes in lake sediment accumulation were obtained by comparing the volume of water within the area surveyed in 1989 with the volume in the same area of the 1954 survey. The 1989 data were corrected for the lake level at which the 1954 survey was referenced.

3.2 WATERSHED SURVEY

Characterization of the current conditions in the Ridinger Lake watershed was oriented toward identifying the principal sources of sediment and nutrient loading. Components of this survey included:

- Hydrologic characterization
- Land use delineation
- Erodible soil evaluation
- Sediment/nutrient modeling.

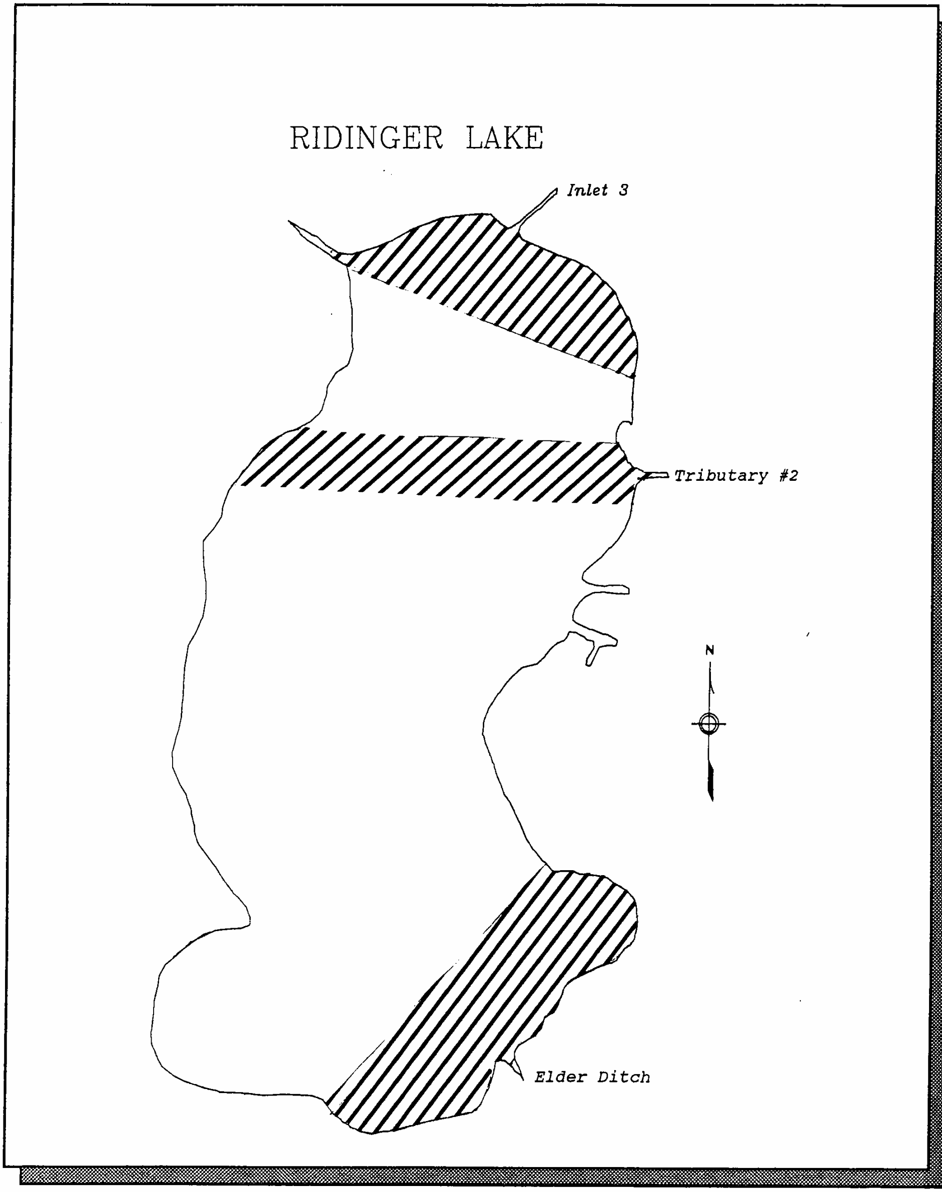


FIGURE 4. Areas of Ridinger Lake surveyed for bathymetric maps.

3.2.1 Hydrological Data

The principal hydrologic parameter of interest in developing a restoration strategy for Ridinger Lake is the hydraulic residence time. This is defined as the length of time required for the entire volume of the lake to be replaced with "new" water from runoff and direct precipitation. The information used in calculating the residence time included the lake volume, average annual runoff for the Ridinger Lake watershed, annual rainfall, and evaporation from the surface of the lake.

3.2.2 Land Use Delineation

Major land use patterns in the Ridinger Lake watershed were identified using recent aerial photographs (1:2,000 scale) of the lake and watershed, USGS topographic maps (1:24,000 scale), and site reconnaissance. Aerial photographs of the Kosciusko County portion of the watershed were taken in 1985, and those of the Whitley County portion were taken in 1987. Several steps were necessary to develop the final land use map of the entire watershed.

First, the watershed boundary was outlined on topographic maps and digitized into IBM-PC compatible data files along with key geographical features (e.g., lake shorelines, streams, roads, and towns). Land use within the watershed was delineated using aerial photographs and assigned to one of sixteen unique categories. The land use types used are shown in Table 7. The border of each land use type was

TABLE 7. Land use categories designated in the watershed survey.

1.	Water Surface
2.	Wetlands (including approximate stream corridors)
3.	Forest (tree groups larger than 0.25 acre)
4.	Open Land/Vacant Lots (no structures or livestock, fallow)
5.	Pasture (grazed lands)
6.	Row Crops (corn, beans, etc.)
7.	Non-row Crops (wheat, hay, etc.)
8.	Orchard
9.	Feedlot
10.	Low Density Residential/Rural (1 dwelling/acre)
11.	Medium Density Residential (2-5 dwellings/acre)
12.	High Density Residential (6 or more dwellings/acre)
13.	Commercial/Industrial (industrial parks, malls)
14.	Institutional (schools, parks, golf courses)
15.	Bare/Unseeded Ground (construction sites)
16.	Resource Extraction (borrow pits, timber sites)

digitized into IBM-PC compatible data files. These files were then overlain onto the watershed boundary and geographical feature data files. Coverage maps and tabular summaries of land use in the watershed, as well as the data files to produce them, were developed using IS&T proprietary software. The results of this task were used as input parameters for modeling sediment and nutrient loading to the watershed (Section 3.2.4).

3.2.3 Erodible Soils Evaluation

The Kosciusko and Whitley County Soil and Water Conservation Districts (SWCD) have prepared detailed analyses of soil erodibility in these two counties. Additionally, Dr. Peter Hippensteel (Tri-State University, Angola) has identified specific areas of highly erodible soils in the Kosciusko County portion of the Ridinger Lake drainage basin. These studies were the primary sources of information used in characterizing the extent of erodible soils within the watershed.

3.2.4 Sediment/Nutrient Modeling

Information on land use, climate, soils, and hydrology were combined to provide input parameters for use in the Agricultural Nonpoint Source Pollution Model (AGNPS), a system developed by the U.S. Department of Agriculture-Agricultural Research Service in cooperation with the Minnesota Pollution Control Agency and the Soil Conservation Service. The PC-based model was designed to simulate the sediment and nutrient contributions from watersheds under predefined hydrologic conditions. AGNPS operates on a grid basis and requires that the watershed be divided into a series of discrete squares, or cells. Twenty-two input parameters, covering a wide range of physical and chemical characteristics, are assigned to each cell (Table 8). Sediment and nutrients are routed through the watershed; their concentrations in each cell being a function of upstream loading and the unique cell attributes, which can either increase or diminish the nonpoint pollution load. Sediment, nutrient, and hydrologic characteristics may be summarized for any cell along the flow path and at the watershed outlet. The model also allows the user to highlight cells with specific characteristics, such as high sediment phosphorus yield. In addition, land use and other characteristics may be hypothetically altered to determine the potential effect of future changes on sediment and nutrient loading. The model provides estimates for single precipitation events only, so the user must define a "design storm" for the analysis.

Based on recommendations of AGNPS developers, the Ridinger Lake watershed was divided into a series of 40 acre cells. Each cell was characterized according to the parameters listed in Table 8. The design storm chosen was a two year, 24-hour event. This is defined as the largest storm that can be expected to occur over a 24-hour period once every two years, based on a 30 year period of record. For Ridinger Lake, this was a 2.7 in. rainfall (U.S. Department of Commerce, 1966). Maps indicating problem areas with respect to nutrient and sediment inputs were produced using the AGNPS Graphical Interface System.

TABLE 8. Input parameters used in the AGNPS model[1]

TITLE	DESCRIPTION
Cell Number	ID of current cell
Receiving Cell	ID of cell receiving outflow from current cell
SCS Curve Number	Relates runoff mass to rainfall mass (inches)
Field Slope	Mean slope of fields (%)
Slope Shape	Indicates concave, convex or uniform slope shape
Slope Length	Indicates average field slope length (feet)
Channel Slope	Mean slope of stream channel (%)
Side Slope	Mean slope of stream channel banks (%)
Roughness	Manning's Roughness Coefficient for channels
Soil Erodibility	K-Factor from Universal Soil Loss Equation
Crop Practice	C-Factor from Universal Soil Loss Equation
Conserv. Practice	P-Factor from Universal Soil Loss Equation
Surface Condition	Indicates degree of land surface disruption
Aspect	Principal drainage direction
Soil Texture	Indicates sand, silt, clay or peat
Fertilization	Indicates level of added fertilizer
Incorporation	Indicates % fertilizer left on soil after storm
Point Source Flag	Indicates presence/magnitude of any point source
Gully Source	Override estimate of gully erosion magnitude
COD	Level of chemical oxygen demand generated
Impoundment Flag	Indicates presence/absence of terrace systems
Channel Flag	Indicates presence/absence of defined streams

[1] Parameters represent estimated conditions within each cell.

SECTION 4. RESULTS AND DISCUSSION

4.1 LAKE SURVEY

This investigation included in-situ, chemical and biological water quality measurements; sediment analyses; aquatic macrophyte distribution mapping; and bathymetric mapping. These data were used to summarize summertime conditions in the lake and assess its current trophic status.

4.1.1 In-situ Measurements

In-situ water quality measurements are presented in Figure 5 and Table 9. These data indicate that Ridinger Lake was thermally stratified at the time of sampling, with the thermocline beginning at a depth of approximately 10 feet.

TABLE 9. Ridinger Lake In-situ water quality measurements. (24 August 1989)

DEPTH (ft)	TEMP (C)	DO (mg/L)	pH	% TRANS.	SECCHI DISK (ft)
0.0	24.1	9.26	8.4		3.28
3.0	24.1	9.26	8.4	18.1	
5.0	23.9	9.28	8.4		
10.0	22.7	2.39	7.7		
15.0	21.2	0.21	7.5		
20.0	14.5	0.15	7.5		
25.0	11.6	0.13	7.5		
30.0	9.9	0.09	7.5		
35.0	9.4	0.10	7.5		
37.5	9.2	0.10	7.5		
39.5	bottom				

Dissolved oxygen (DO) concentrations were constant and supersaturated at 9.3 mg/L from the surface to a depth of five feet. At a depth of ten feet, the oxygen concentration dropped sharply. Anoxic conditions were measured from this depth to the lake bottom. The DO profile (Figure 5) is characteristic of eutrophic lakes.

The pH distribution in the water column was typical of a productive, stratified lake. Values above the thermocline were higher than those below, ranging from 7.7 to 8.4. The higher values above the

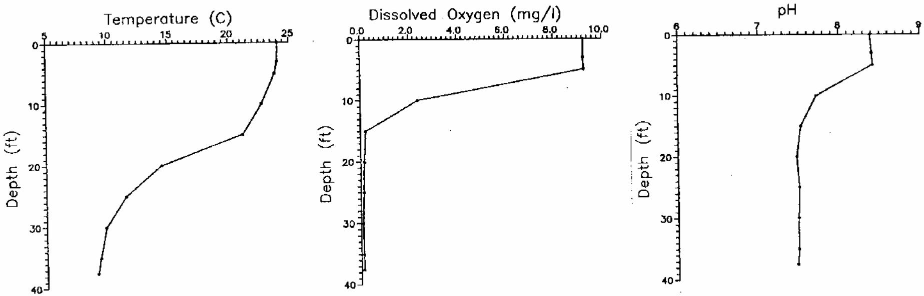


FIGURE 5. Temperature, dissolved oxygen and pH profiles observed at the in-lake sampling station. (24 August 1989).

thermocline are a result of the photosynthetic utilization of carbon dioxide (CO_2), a weak acid. As CO_2 is utilized and its concentration in the water column is reduced, pH increases.

4.1.2 Chemical Measurements

Water quality analyses were conducted on both in-lake samples and storm event tributary samples. Results for both types of samples collected are discussed below.

In-Lake Samples. The results of water quality analyses for in-lake samples are shown in Table 10. In general, the values are indicative of eutrophic conditions. Much higher concentrations of TP, OP, TKN, $N\text{-}NH_4$ and TSS were found in the bottom sample than in either the mid-depth or surface samples. These data reflect nutrient release from lake sediments under anoxic conditions. The high TSS concentration in the bottom sample may indicate disturbance of the bottom sediments during sampling. Such a disturbance may also have contributed to the high nutrient concentrations in the bottom sample.

The nitrogen to phosphorus ratio (N:P) is a common tool for examining the relative importance of these two critical algal nutrients. These nutrients are quickly taken up in their soluble forms (i.e., orthophosphorus and nitrate). Moreover, algae are characteristically luxury consumers of phosphorus, taking up available forms in excess of immediate physiological requirements. Thus, the concentrations of the soluble forms are not necessarily indicative of available supply (Welch, 1980). However, the ratio of the total concentrations can be used to assess which nutrient will be limiting to plant growth (i.e, the first to be used completely following continued growth) under optimum physical conditions where light and temperature are not inhibiting.

Nitrogen is rarely limiting in freshwater systems due to its abundance in the atmosphere and availability through nitrogen fixation by blue-green algae. Phosphorus is generally the limiting nutrient in these systems. However, in eutrophic lakes where phosphorus is extremely abundant, nitrogen may be limiting. As a general rule, if the N:P ratio is 17 or greater, phosphorus is most likely the limiting nutrient. N:P ratios less than 13 are usually indicative of nitrogen limitation (Cooke, et. al., 1986). Either nitrogen or phosphorus may be limiting when ratios are between 13 and 17.

The N:P ratio of the surface sample was 13.8, indicating neither phosphorus nor nitrogen limitation. However, soluble phosphorus was below detection limits at the surface, suggesting that all available forms of phosphorus in the water column had been taken up by the algal population. The mid-depth N:P ratio (26.3) clearly falls within the range of phosphorus limited systems. The low N:P ratio of the bottom sample (7.7) suggests nitrogen limitation, but is clearly the result of an extraordinarily high phosphorus concentration at that depth. In summary, the lake appears to be phosphorus limited.

Storm Event Samples. Table 11 presents the storm event water quality data for the three tributaries to Ridinger Lake. The samples were collected on November 15, 1989 during a storm of moderate intensity;

TABLE 10. Ridinger Lake water quality results for in-lake samples.

SAMPLE ID	SAMPLE DEPTH (ft)	DATE COLLECTED	TIME COLLECTED	CHL A (mg/m3)	FECAL COLIFORM (#/100ml)	N-NH4 (mg/L)	NO3 (mg/L)	TKN (mg/L)	OP (mg/L)	TP (mg/L)	TSS (mg/L)	N:P Ratio
R-SURF	0.0	08/24/89	12:15	14.5	252	<0.005	0.125	0.579	<0.005	0.051	2.3	13.8
R-MID	20.0	08/24/89	12:25	4.8	10	0.340	0.322	0.889	0.029	0.046	7.0	26.3
R-BOTTOM	37.5	08/24/89	12:35	3.2	190	2.450	0.117	3.258	0.044	0.440	38.7	7.7

CHL A = Chlorophyll a; FECAL COLIFORM = Fecal Coliform Bacteria; N-NH4 = Ammonia; NO3 = Nitrate;
TKN = Total Kjeldahl Nitrogen; OP = Ortho Phosphorus; TP = Total Phosphorus; TSS = Total Suspended Solids
< = Value Lower Than Detection Limit

TABLE 11. Ridinger Lake water quality results for tributary samples.

SAMPLE ID	DATE COLLECTED	TIME COLLECTED	CHL A (mg/m3)	N-NH4 (mg/L)	NO3 (mg/L)	TKN (mg/L)	OP (mg/L)	TP (mg/L)	TSS (mg/L)
TRIB - #1	11/15/89	15:20	5.13	0.037	10.670	2.735	0.130	0.510	221.0
TRIB - #2	11/15/89	15:10	0.53	0.009	0.674	1.189	<0.006	0.197	4.7
ELDER DCH	11/15/89	15:05	17.62	0.044	0.494	1.066	0.111	0.253	46.7

CHL A = Chlorophyll a; N-NH4 = Ammonia; NO3 = Nitrate; TKN = Total Kjeldahl Nitrogen;
OP = Ortho Phosphorus; TP = Total Phosphorus; TSS = Total Suspended Solids
< = Value Lower Than Detection Limit

rainfall during this 24 hour period was 1.21 inches, less than half the maximum amount (2.4 inches) that can be expected to occur on a frequency of one year (U.S. Department of Commerce, 1966). Rainfall during the 24 hours prior to the date of sample collection was 0.06 inches. Precipitation data were recorded at the Warsaw airport.

The TP concentration in Tributary #1 (0.51 mg/L) was approximately twice that observed in Elder Ditch or in Tributary #2. Nitrate, OP and TKN concentrations were also highest in Tributary #1. The observed TSS concentration (221 mg/l) indicates that this tributary is contributing a much greater sediment load than the other inflows; the TSS concentration was approximately five times higher than that in Elder Ditch and over 50 times the level observed in Tributary #2. Tributary #1 drains an area of farmland with sections of highly erodible soils contiguous with the stream channel. The high nutrient and TSS levels indicate nutrient and sediment input are likely to be associated with these soils and land use practices in the sub-basin.

The nitrate concentration observed in Tributary #1 (10.67 mg/L) was far greater than concentrations observed in the other tributaries. The Kosciusko County Sanitarian indicated that nitrate toxicity in groundwater has been suspected in the northern portion of this sub-basin. IS&T has no data to confirm this, however the Kosciusko County Sanitarian reported that an incident involving the death of calves was likely due to nitrate in the cattle's drinking water (Kosciusko County Sanitarian, pers. comm).

4.1.3 Biological Measurements

THIS IS ESSENTIALLY THE SAME AS IN THE DRAFT

The results of the Chl a analyses indicate that phytoplankton biomass was largely confined to the surface. The pigment concentration observed (14.5 ug/l^3) suggests highly productive surface waters. As expected, the values dropped sharply in the mid and bottom waters, where light and temperature levels become limiting to phytoplankton.

The results of phytoplankton identification and enumeration showed a diverse algal community. Thirty six species in five classes were identified (Table 12). The algal community was dominated by blue-greens, which comprised over 90% of the 20 foot tow and over 80% of the five foot tow (Figures 6a and 6b). Oscillatoria tenuis was dominant at both 5 feet and 20 feet. Also prevalent at 5 feet was Microcystis aeruginosa, while Oscillatoria planctonica co-dominated at 20 feet. Other numerically important species included the blue-greens Anabaena planctonica, Aphanizomenon flosaquae, and the green algae Pediastrum simplex. Blue-green algal dominance is an indication of eutrophic conditions in the lake (Wetzel, 1983).

Significant concentrations of fecal coliform bacteria were present in each water column sample. The highest fecal count occurred in the surface sample (252 colonies per 100 mL of sample). This may have been the result of the rain event which occurred the evening prior to sampling. The bottom sample also showed fairly high levels of fecal coliform. All three samples had counts below the IDEM standard for

TABLE 12. Ridinger Lake Phytoplankton Count. (24 August 1989)

	CELLS PER SAMPLE	
	5 FT. TOW	20 FT. TOW
Sample Volume Total (ml)	91.0	108.0
Volume of Sample settled for ident. (ml)	3.0	3.0
SPECIES		
Chlorophyta (green algae)		
Ankistrodesmus convolutus	128,000	869,000
Ankistrodesmus nanoselene	18,300	43,500
Chlamydomonas globosa	18,300	
Chlamydomonas snowii	21,700	
Closteriopsis longissima	72,500	43,500
Coelastrum dubium	*	
Dictyosphaerium pulchellum	458,000	
Pandorina morum	86,900	
Pediastrum simplex	531,000	*
Scenedesmus bijuga	43,500	
Sphaerocystis schroeteri	*	
Total Chlorophyta cells per sample	1,226,100	1,108,100
Total Chlorophyta cells per ml settled	13,473	10,260
Chrysophyta (diatoms, chrysophytes, etc.)		
Fragilaria crotonensis	604,000	
Melosira granulata	36,600	261,000
Melosira sp	476,000	
Nitiszchia sp	18,300	
Stephanodiscus sp	21,700	
centric diatoms < 10u	54,900	130,000
pennate diatoms > 25u	21,700	
Total Chrysophyta cells per sample	1,189,800	434,400
Total Chrysophyta cells per ml settled	13,074	4,022
Euglenophyta (euglenoids)		
Euglena sp	18,300	
Total Euglenophyta cells per sample	18,300	0
Total Euglenophyta cells per ml settled	201	0

TABLE 12. Ridinger Lake phytoplankton count (concluded). (24 August 1989)

	CELLS PER SAMPLE	
	5 FT. TOW	**20 FT. TOW**
Sample Volume Total (ml)	91.0	108.0
Volume of Sample settled for ident. (ml)	3.0	3.0
Pyrrophyta (yellow-brox algae)		
Ceratium hirudinella	18,300	
Cryptomonas erosa	18,300	21,700
Cryptomonas pusilla	18,300	65,200
Total Pyrrophyta cells per sample	54,900	86,900
Total Pyrrophyta cells per ml settled	603	805
Cyanophyta (blue-green algae)		
Anabaena flosaquae		1,540,000
Anabaena planctonica	659,000	869,000
Aphanizomenon flosaquae	568,000	575,000
Aphanocapsa pulchra		696,000
Aphanothece gelatinosa		*
Chroococus dispersus	476,000	
Lyngbya birgei	*	869,000
Merismopedia punctata		174,000
Merismopedia tenuissima	435,000	1,040,000
Microcystis aeruginosa	2,200,000	
Oscillatoria planctonica	971,000	9,480,000
Oscillatoria tenuis	2,670,000	10,600,000
blue-green monads	725,000	130,000
blue-green filaments	2,070,000	
unidentified cells		43,500
Total Cyanophyta cells per sample	10,774,000	26,016,500
Total Cyanophyta cells per ml settled	118,393	240,895
Total phytoplankton cells per sample	13,263,100	27,645,900
Total cells per ml settled	145,745	255,982

TOTAL NOS. AND REST OF TABLE 12 [illegible]

* Species was found during scans of the subsample but not seen during the actual count.

whole body contact recreation in lakes and reservoirs (i.e., 400 colonies per 100 ml sample). It is not possible to identify the source of fecal contamination from the available data. However, possible sources include waterfowl, septic system overflow, and animal waste, including pet droppings.

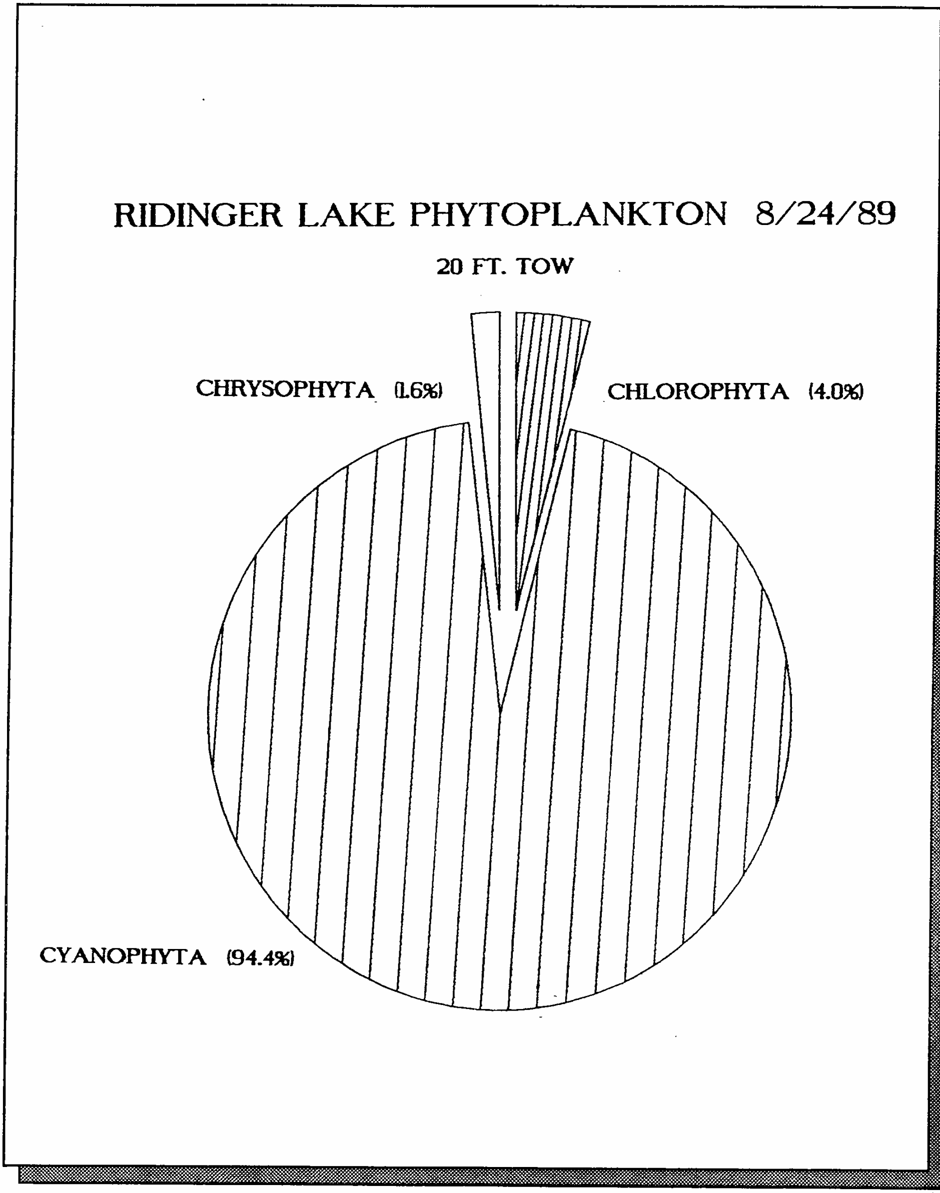


FIGURE 6a. Results of phytoplankton analysis for 20 ft. tow.

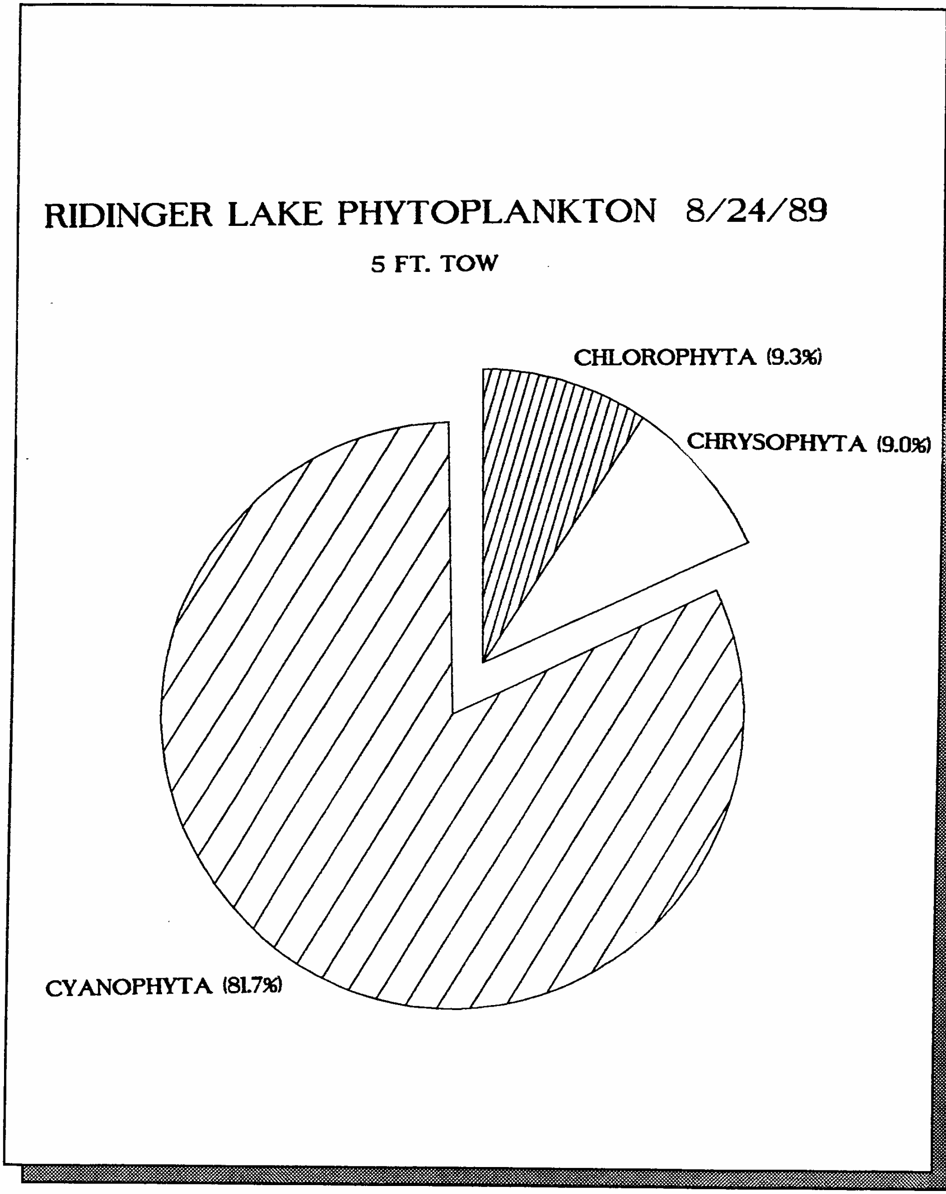


FIGURE 6b. Results of phytoplankton analysis for 5 ft. tow.

4.1.4 Trophic State Assessment

The biological, chemical and physical characteristics of a lake can be incorporated into an index number to describe its trophic state. Historically, trophic classifications have been based on the division of the trophic continuum into a series of classes. Traditional systems divide the continuum into three classes (i.e., oligotrophic, mesotrophic and eutrophic), but frequently offer no clear delineation of these divisions. Calculating a trophic state index allows a quantitative description of the degree of eutrophication in a lake, and provides a basis for numerically comparing the lake's trophic status over a period of time and for comparing its trophic state against that of other lakes.

There are several numerical trophic classification systems currently used within the scientific community. A previous trophic state assessment of Ridinger Lake was conducted using the BonHomme Eutrophication Index and is documented in the Indiana Lake Classification System and Management Plan (IDEM, 1986). The index was developed by Harold BonHomme of IDEM. Index points are assigned based on diverse chemical, physical and biological measurements in the lake. A lake may receive a Eutrophication Index (EI) number ranging from 0 to 75, with values near 0 being the least eutrophic.

Another numerical index that is widely used for trophic state assessment is the Carlson Trophic State Index (TSI). Carlson (1977) based his index on algal biomass using the log transformation of Secchi disk transparency, a physical measurement, as an estimate of biomass. Since Chl a and TP concentrations are often correlated with transparency, a TSI number may also be calculated from these biological and chemical measurements. All three measurements are taken from surface waters where phytoplankton productivity is at its peak. The equations used for computing the Carlson TSI are:

$$TSI(SD) = 10\left(6 - \frac{\ln SD}{\ln 2}\right)$$

Where:

TSI (SD) = TSI based on Secchi disk transparency

SD = Secchi transparency (m)

$$TSI(Chla) = 10\left(6 - \frac{2.04 - 0.68 \ln Chla}{\ln 2}\right)$$

Where:

TSI (Chl a) = TSI based on chlorophyll concentration

Chl a = Chlorophyll a (ug/L^3)

$$TSI(TP) = 10\left(6 - \frac{\ln\frac{48}{TP}}{\ln 2}\right)$$

Where:

TSI (TP) = TSI based on total phosphorus concentration

TP = Total phosphorus (ug/L^3)

The Carlson TSI classifies lakes on a scale of 0 to 100, with each major scale division (i.e., 10, 20, 30, ...) representing a doubling in algal biomass. Under ideal circumstances, the three separate TSI values should be similar. Under realistic conditions, however, the index values will exhibit some variability. It is this variability that reveals the basic differences in the ecological functioning of the aquatic system. The accuracy of Carlson's TSI based on the Secchi disk measurement alone is diminished by the presence of non-algal particulate matter or highly colored water. The index number derived from the Chl a values, when available, is best for estimating algal biomass, and priority should be given for its use as a trophic state indicator (Carlson, 1977).

A BonHomme Eutrophication Index (EI) number was calculated for Ridinger Lake using the water quality data collected during the August 1989 field survey. The index used for this calculation is not directly comparable to that documented by IDEM (1986). The index has been revised, by the LEP staff, within the phytoplankton scale adjusted to reflect the number of organisms present per liter of lake water sampled (IDNR, 1990). Table 13 presents the revised BonHomme Eutrophication Index, and the details of the Ridinger Lake calculation. There is one source of uncertainty in this EI calculation which should be noted. The phytoplankton sample from the thermocline was collected in a manner inconsistent with the technique used by BonHomme. A closed sample from the thermocline only, rather than a vertical tow from the thermocline to the surface, is the method used on lakes previously sampled by IDEM. Based on the recommendations of Mr. BonHomme (pers. comm.), the data collected from the 5 foot tow was used to estimate the phytoplankton count in the thermocline.

Previously, the IDEM calculated an EI number of 58 for Ridinger Lake. A re-evaluation of the data used DRAFT for this calculation resulted in an EI number of 63 (BonHomme, pers. comm.). The EI number based on data collected in 1989 was calculated to be 42, placing the lake in the Class Two trophic category. Lakes in the Class Two category (25-50 eutrophy points) are of intermediate quality, usually productive and exhibit subtle trophic changes. These lakes frequently support extensive concentrations of macrophytes and/or algal, but seldom to the extent of significantly impairing lake uses. The majority of Indiana's natural lakes are included on the Class Two category (IDEM, 1986).

HIGHLIGHTS WERE CHANGED FROM DRAFT

TABLE 13.Bonhomme Eutrophication Index calculations for Ridinger Lake (24 August 1989).

PARAMETER AND RANGE	RANGE VALUE	RANGE OBSERVED	POINT SCORE
Total Phosphorus (mg/L)			
Observed mean = 0.18			
At least 0.03	1		0
0.04 to 0.05	2		0
0.06 to 0.19	3	X	3
0.20 to 0.99	4		0
Greater than 0.99	5		0
Soluble Phosphorus (mg/L)			
Observed mean = 0.02			
At least 0.03	1		0
0.04 to 0.05	2		0
0.06 to 0.19	3		0
0.20 to 0.99	4		0
1.00 or more	5		0
Organic Nitrogen (mg/L)			
Observed mean = 0.6			
At least 0.50	1		0
0.60 to 0.80	2	X	2
0.90 to 1.90	3		0
2.0 or more	4		0
Nitrate (mg/L)			
Observed mean = 0.2			
At least 0.3	1		0
0.40 to 0.80	2		0
0.90 to 1.90	3		0
2.0 or more	4		0
Ammonia (mg/L)			
Observed mean = 0.9			
At least 0.30	1		0
0.40 to 0.50	2		0
0.60 to 0.90	3	X	3
1.0 or more	4		0
Percent oxygen saturation at 5 feet			
Observed value = 11,290			
114% or less	0	X	0
115% to 119%	1		0
120% to 129%	2		0
130% to 149%	3		0
150% or more	4		0

TABLE 13. Bonhomme Eutrophication Index calculations for Ridinger Lake (concluded). (24 August 1989).

PARAMETER AND RANGE	RANGE VALUE	RANGE OBSERVED	POINT SCORE	
Percent of Water Column with at least 0.1 mg/L of DO				
Observed value = 77%				
28% or less	4		0	
29% to 49%	3		0	
50% to 65%	2		0	
66% to 75%	1		0	
76% to 100%	0	X	0	
Secchi Disk Transparency				
Observed value = 3 feet				
5 feet or less	6	X	6	
Greater than 5 feet	0		0	
Light Transmission at 3 Feet				
Observed value = 18%				
0% to 30%	4	X	4	
31% to 50%	3		0	
51% to 70%	2		0	
71% or greater	0		0	
Total Plankton from 5 foot Tow (#/L)				
Observed value = 119,278/L				
Less than 4,700/L	0		0	
4,701/L to 9,500/L	1	HIGHLIGHTS	0	
9,501/L to 19,000/L	2	CHANGED FROM	0	
19,001/L to 28,000/L	3	DRAFT	0	
28,001/L to 57,000/L	4		0	
57,001/L to 95,000/L	5		0	
95,001/L or more	10	X	10	
Blue-green dominance	5	X	5	
Total Plankton from Thermocline Tow (#/L)				
Observed value = 119,278/L				
Less than 9,500/L	0		0	
9,501/L to 19,000/L	1		0	
19,001/L to 47,000/L	2		0	
47,001/L to 95,000/L	3		0	
95,001/L to 190,000/L	4	X	4	9 vs 20
190,001/L to 285,000/L	5		0	IN DRAFT
285,001/L or more	10		0	
Blue-green dominance	5	X	5	
Population of 950,000/L or more	5		0	
INDEX VALUE			42	

A direct comparison of the current and previous EI numbers was not carried out, as the revised BonHomme Eutrophication Index was used to calculate only the current EI number. However, a comparison of the chemical and physical data used to calculate the previous EI number with the current data (excepting the phytoplankton counts) indicates a decrease in concentration for the majority of the parameters measured with the exception of TP and N-NH4. The lake conditions at the time of sampling, which was after rain event, may also have had an effect on those concentrations. The rain event would serve to increase the input of TP and sediments from the watershed.

Calculation of the Carlson TSI was based on the Chl a and TP concentrations in the surface waters, as well as the Secchi disk transparency of Ridinger Lake. Table 14 presents the results of these calculations. The range of TSI numbers was between 57 and 61. TSI numbers of 50 to 60 are characteristic of the lower boundary of classical eutrophy. Lakes with TSI numbers in this range are characterized by decreased water transparency, increased macrophyte growth, and anoxic hypolimnia during the warmer summer months. As TSI values increase to the range of 60 to 70, blue-green algae become dominant and algal scums are probable (Carlson, 1979).

TABLE 14. Carlson Trophic State Index calculations for Ridinger Lake (24 August 1989).

SECCHI DISK (m)	TSI (SD)	CHL a ($\mu g/L^3$)	TSI (CH1)	TP (ug/L^3)	TSI (TP)
1.0	60	14.52	57	51.0	61

A comparison of the calculated TSI values shows that the Secchi disk and TP based values are nearly equivalent, while the Chl a based value was marginally lower. This indicates that non-algal particulate matter dominated light attenuation at the time of sampling (Carlson, 1983). It is likely that the rain event prior to sampling increased the sediment load to the lake, resulting in a lower Chl a based TSI than either the TP or Secchi disk based values.

Both the BonHomme EI and the Carlson TSI classify Ridinger Lake as being near the lower boundary (early stages) of eutrophication at the time of sampling. The current BonHomme EI number (42) places the lake in Trophic Class Two, although the actual number is closer to the boundary between Class Two and Class Three. Similarly, the Carlson TSI values are characteristic of a lake moving into classical eutrophy. It should be noted that the data used to construct these indices are derived from a single sampling event and are only representative of lake conditions on a single day in mid-summer. Better representation of trophic state could be attained through increased lake monitoring throughout the summer growing season. Such high resolution sampling was beyond the scope of this investigation.

4.1.5 Sediment Sample Results

The results of analyses on sediment samples collected from the Tributary #1 and from Elder Ditch are shown in Table 15. All samples were collected on October 12, 1989. For comparison purposes, this table also shows mean background concentrations in sediments at 83 sites throughout Indiana surveyed by IDEM from 1985 to 1987 (IDEM, 1988). These mean values represent sediment concentrations at sites upstream of all known point sources of pollution, including industrial discharges and combined sewer overflows. As such, they are considered to represent unpolluted lake and stream sediments statewide. The IDEM provides these estimates because no criteria for sediment concentrations of priority pollutants have been established by the state or federal government. As guidelines for interpreting sediment data, IDEM has defined four levels of concern: low, medium, high, and unknown. Low concern is defined as 2-10 times background levels, medium concern as 10-100 times background, and high concern as any concentration greater than 100 times background.

TABLE 15. Results of Ridinger Lake sediment sample analyses.

SAMPLE ID	DATE COLLECTED	TIME COLLECTED	TP (mg/Kg)	TKN (mg/Kg)	CADMIUM (mg/Kg)	CHROMIUM (mg/Kg)	LEAD (mg/Kg)	NICKEL (mg/Kg)	ZINC (mg/Kg)
TRIB #1 - 1	10/12/89	13:40	900	3,200	1.10	16.8	22.60	18.4	59.4
TRIB #1 - 2	10/12/89	13:55	910	3,600	1.20	18.3	26.70	19.4	81.3
TRIB #1 - 3	10/12/89	14:10	780	3,500	2.20	3.1	20.50	12.1	21.0
TRIB #1 - 4	10/12/89	14:25	680	3,200	1.60	11.0	24.80	23.5	56.2
TRIB #1 - 5	10/12/89	14:30	370	1,900	1.60	3.9	16.50	13.0	27.5
ELDER - 1	10/12/89	14:50	680	3,300	1.30	11.0	17.20	17.7	76.1
ELDER - 2	10/12/89	14:55	720	4,100	1.10	8.5	15.03	15.7	81.6
ELDER - 3	10/12/89	15:07	450	2,700	1.20	13.0	18.00	19.3	83.9
ELDER - 4	10/12/89	15:12	410	2,300	1.10	7.9	14.00	14.5	75.5
ELDER - 5	10/12/89	15:25	480	4,600	1.10	5.7	22.10	14.5	55.6
IDEM Background Level			610	1,500	1.00	50.0	150.00	21.0	130.0

Using the IDEM guidelines, all results obtained are in the low concern category. The maximum factor by which a parameter exceeded the background level was three for TKN in sample #5 from Elder Ditch. This sample was located along the Elder Ditch inflow, approximately 100 yards into the lake. A TKN concentration of 4,600 mg/kg was measured in this sample. Sediment TKN concentrations in Elder Ditch were approximately 10% greater than those in Tributary #1.

Total phosphorus concentrations in the Tributary #1 sediments were higher than in Elder Ditch. The maximum TP concentration (910 mg/kg) was less than twice the IDEM background level. In Elder Ditch, TP concentrations ranged from 410 mg/kg to 680 mg/kg. TP values in the Tributary #1 ranged from 370 mg/kg to 910 mg/kg.

With the exception of cadmium, sediment metals concentrations in both ditches were well below background levels. The cadmium concentration in all samples was near or slightly above the IDEM background levels. Sample #3 from the Tributary #1, collected at the mouth of this tributary, had a concentration of 2.2 mg/kg cadmium, just over twice the background level of 1 mg/kg.

The results of the sediment probings in Tributary #1 and Elder Ditch are presented in Table 16. Accurate measurement of sediment depth in Tributary #1, core sites 1 through 4, was not possible. Sediment depth was measured from a boat, and the combined depth of water and sediment at these sites was greater than 10 feet, the length of the measuring rod. Sediment depth shown for these sites is therefore greater than the depths shown. Core site #5 had the only measurable probe refusal depth for Tributary #1, 2.67 feet. Sediment depth at the first four sites was greater than the comparable area in Elder Ditch.

TABLE 16. Results of Sediment Probings at Ridinger Lake.

TRIBUTARY	CORE #	DEPTH TO SEDIMENT (FT.)	SEDIMENT DEPTH (FT.)
Tributary #1	1	3.50	> 6.50
	2	3.25	> 6.75
	3	2.42	> 7.58
	4	3.83	> 6.17
	5	4.08	2.67
Elder Ditch	1	4.33	3.92
	2	5.08	4.25
	3	4.67	5.00
	4	3.08	3.50
	5	7.67	> 2.33

Sediment depth in Elder Ditch increased slightly from core site #1 to site #3, possibly a result of previous dredging. Increased sediment consolidation was noticeable at core #4. At core site #5, the combined depth of water and sediment was again greater than length of the measuring device, and only a minimum estimate was obtained.

4.1.6 Aquatic Vegetation

The aquatic plant survey of Ridinger Lake documented 14 species of aquatic macrophytes (Figures 7a, 7b & 7c and Table 17). The predominant species included water milfoil (Myriophyllum spicatum), a submergent, and two species of floating-leafed water lilies; yellow water lily (Nuphar advena) and white

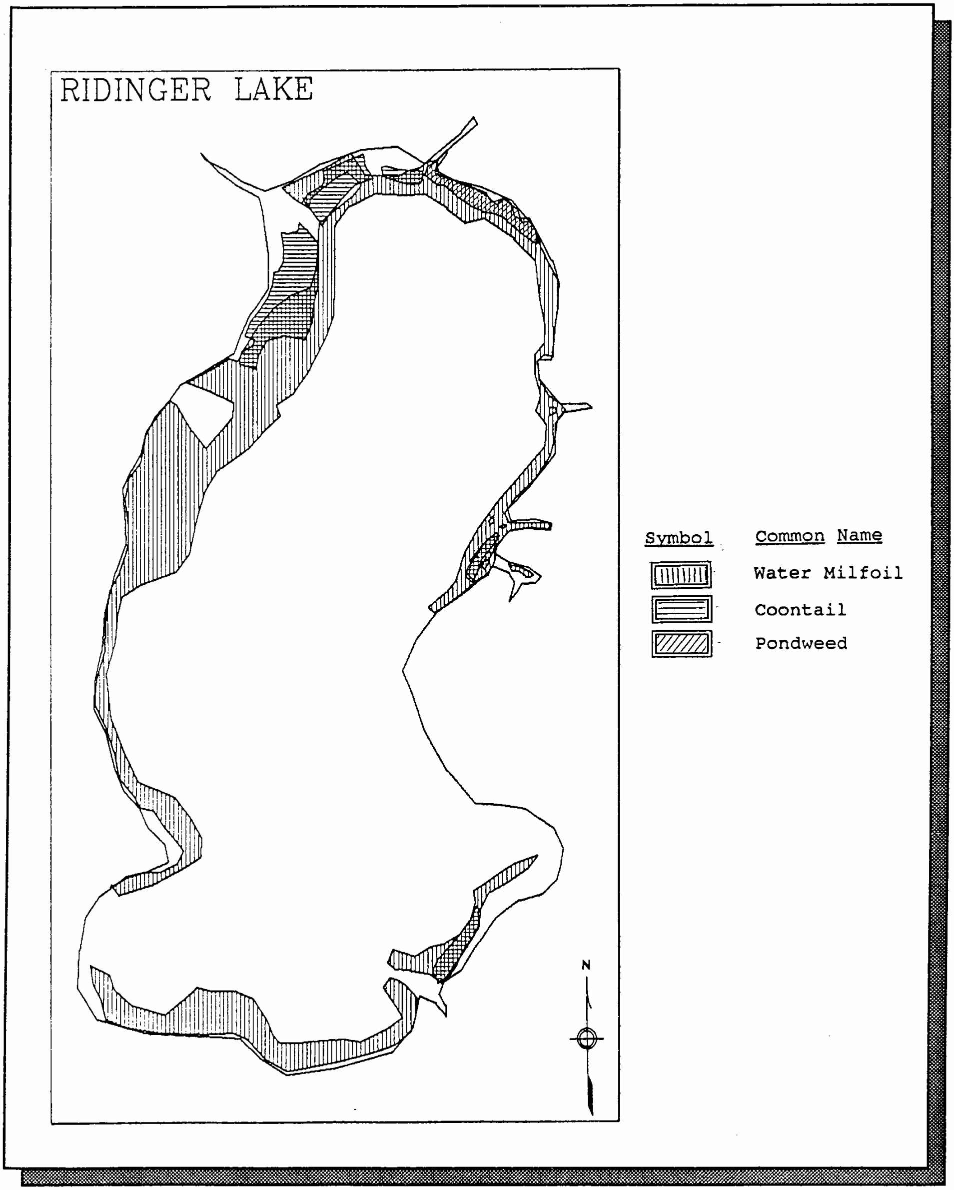


FIGURE 7a. Ridinger Lake aquatic plant survey: submergent species. (26-27 September 1989)

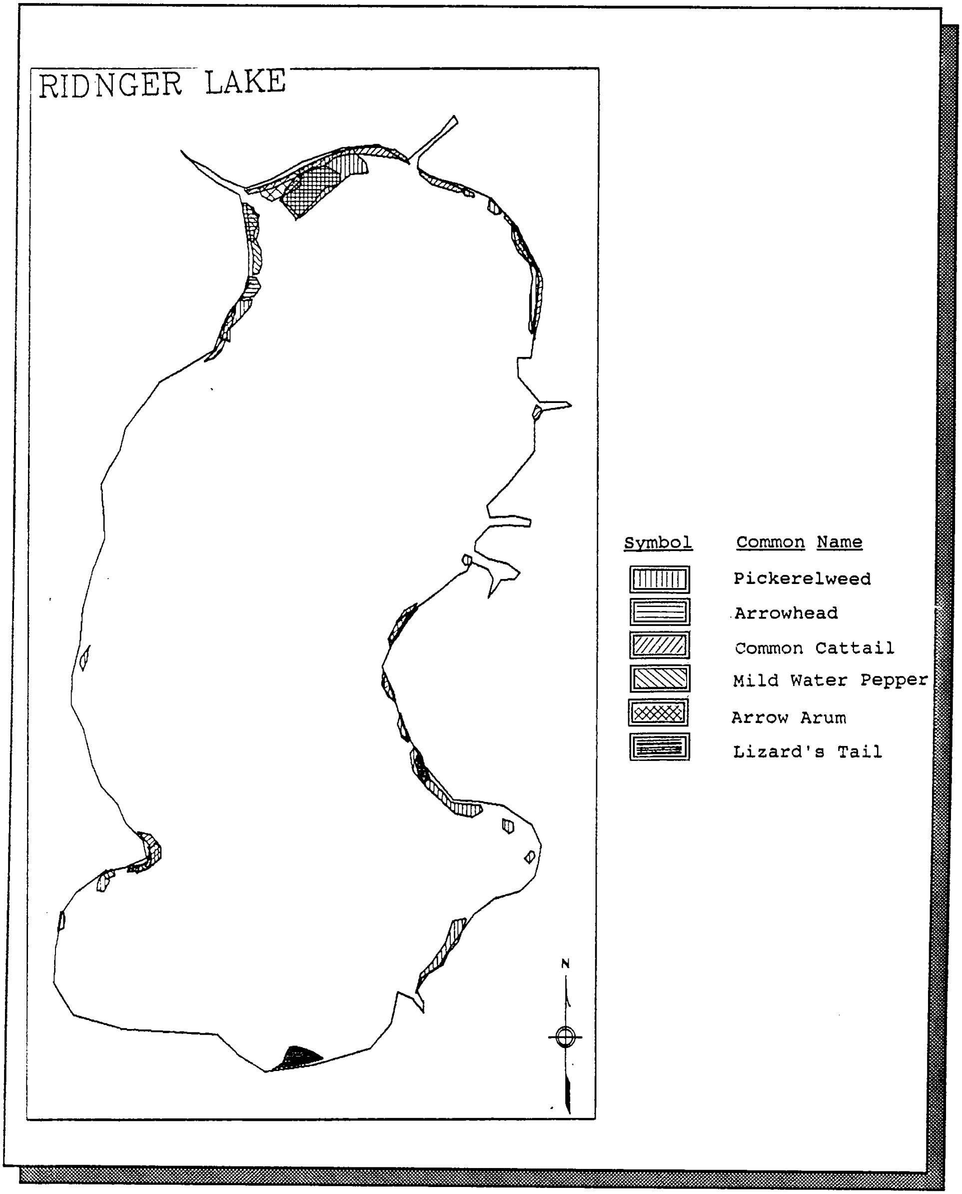


FIGURE 7b. Ridinger Lake aquatic plant survey: emergent species. (26-27 September 1989)

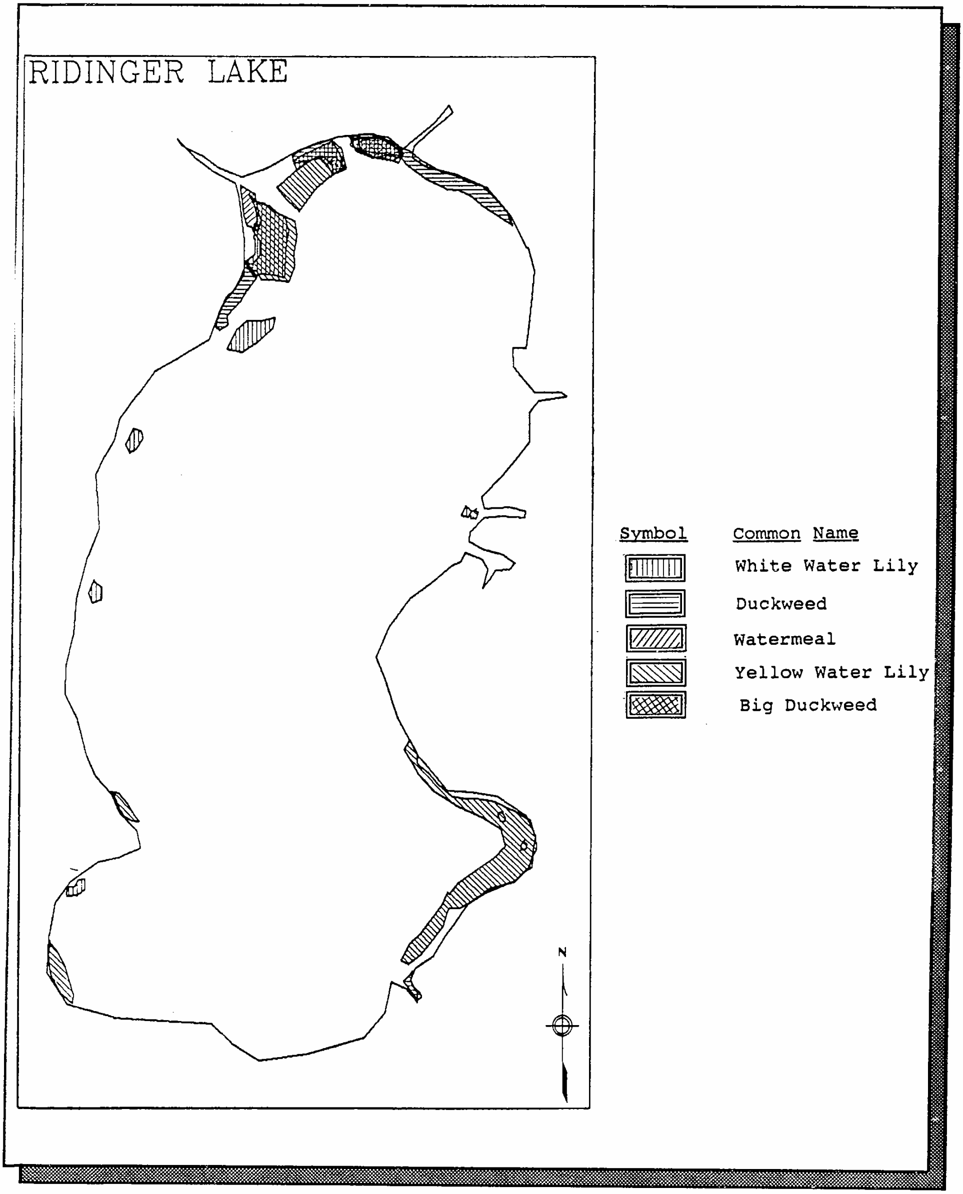


FIGURE 7c. **Ridinger Lake aquatic plant survey: floating species. (26-27 September 1989)**

TABLE 17. Ridinger Lake Aquatic Plant Survey. (26 September 1989)

COMMON NAME	SCIENTIFIC NAME	CATEGORY
Water Milfoil	Myriophyllum spicatum	Submergent
Coontail	Ceratophyllum demersum	Submergent
Pondweed	Potamogeton americanus	Submergent
Pickerelweed	Pontederia cordata	Emergent
Arrowhead	Sagittaria sp.	Emergent
Common Cattail	Typha latifolia	Emergent
Mild Water Pepper	Polygonum hydropiperoides	Emergent
Arrow Arum	Peltandra virginica	Emergent
Lizard's Tail	Saururus cernuus	Emergent
White Water Lily	Nymphaea odorata	Floating
Duckweed	Lemna minor	Floating
Watermeal	Wolffia columbiana	Floating
Yellow Water Lily	Nuphar advena	Floating
Big Duckweed	Spirodela polyrhiza	Floating

water lily (Nymphaea odorata). Water milfoil was present in the shallower waters along the entire lakeshore, with the exception of a small portion of the southeast and southwest shores. The milfoil beds extended up to 70 feet into the lake along portions of the west shore. Yellow water lily was observed growing predominantly in the shallow waters near the lake outlet, and along the southeast shore near the Elder Ditch inlet. White water lily was also present near the lake outlet, and observed along the west shore.

Macrophyte stands at the mouths of both major tributaries and near the lake outlet were believed to be fostered by the development of shoals at these locations. Long term consequences of shoals include decreased water depth, increased light availability for rooted plants and increased build up of organic matter as macrophytes populate the shoal area. The macrophytes can cause navigational problems and may increase the dominance of less desirable fish species. Dense stands of macrophytes, however, will also serve as a buffer to stream/ditch inflows, trapping sediments that enter the lake with runoff.

4.1.7 Bathymetric Survey

Bathymetric maps of the three areas surveyed on the lake are shown in Figures 8a, 8b and 8c. This survey documented a large accumulation of sediment near the Tributary #1 and Elder Ditch inflows since the lake was surveyed in 1954. An accumulation of sediment was also observed in the north central portion of the lake near the intermittent tributary. Table 18 lists the estimated amount of accumulated sediment within each of the tributary regions.

TABLE 18. Sediment Deposition in Tributary Areas of Ridinger Lake (1954-1989).

TRIBUTARY	AREA SURVEYED (ACRES)	ACCUMULATED SEDIMENT (ACRE FEET)
TRIB #1	9.4	22
TRIB #2	13.2	3
ELDER DITCH	19.2	14

The largest volume and most rapid rate of sediment accumulation was observed in the area of Tributary #1. In the 9.4 acres surveyed, an accumulation of 22 acre feet (35,450 yds^3) was calculated. This equates to approximately 2.3 feet of sediment, accumulated at a rate of 0.8 inches per year. The sedimentation rate in the northeast tributary was over three times the rate observed in Elder Ditch and ten times the rate near the intermittent tributary.

Near the Elder Ditch inflow, 19.2 acres were surveyed. An accumulation of 14 acre feet of sediment was calculated (22,590 yds^3), accumulated at a rate of 0.25 inches per year. An unknown quantity of sediment has been removed regularly from the mouth of this ditch. Without this dredging, the actual rate of sedimentation may be equal to or greater than that observed in the northeast tributary.

A small accumulation of sediment was also measured near the mouth of the intermittent tributary. An area of 13.2 acres was surveyed in this region of the lake. A decrease in lake volume of three acre feet was calculated (4,840 yds^3 of sediment accumulated). Over the 35 year period of comparison, of accumulation of 0.08 inches per year was calculated for the intermittent tributary.

In total, between 1954 and 1989, approximately 39 acre feet of sediment (62,929 yds^3) were added to the 41.8 acres of the lake surveyed. The bathymetric survey did not cover the entire lake, however the majority of sedimentation is likely to have occurred in these three areas. The overall rate of

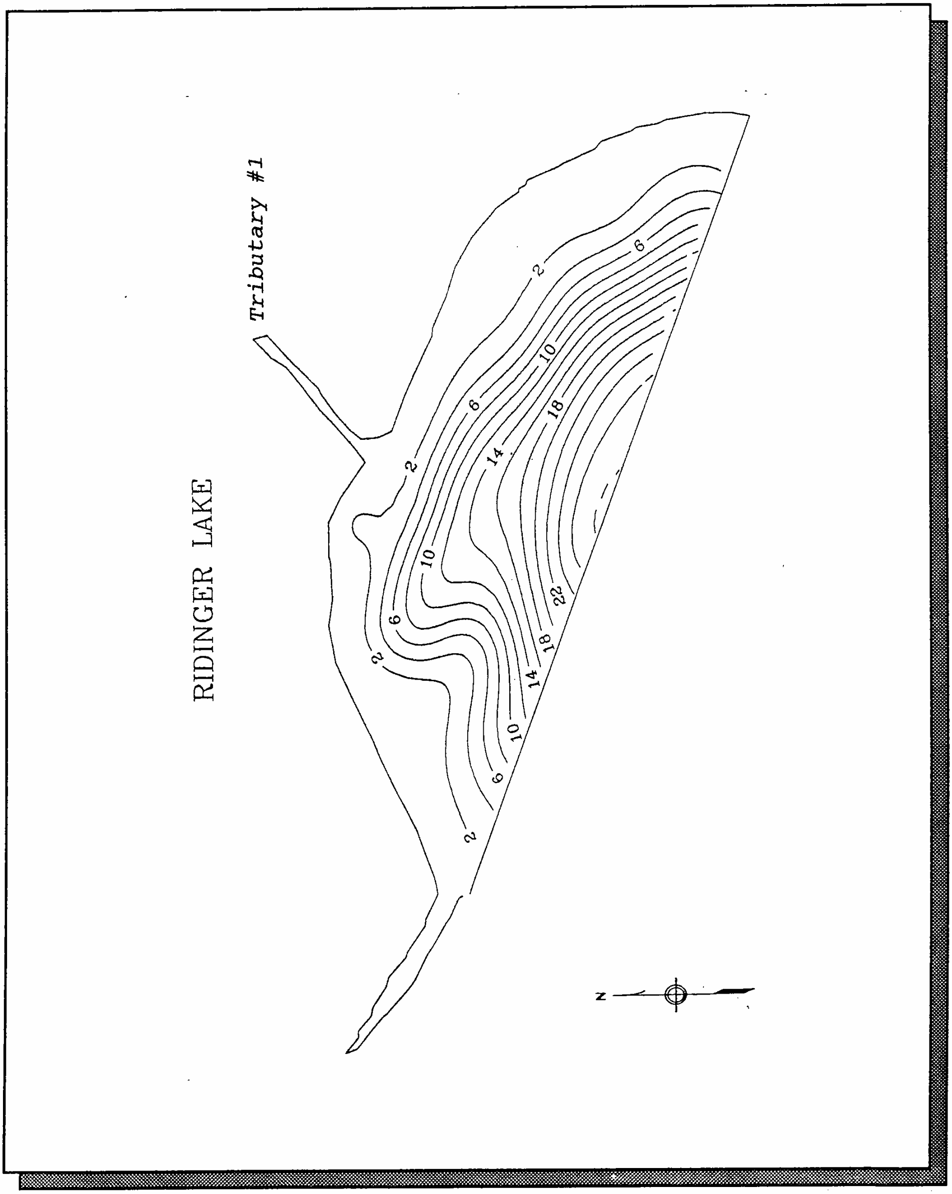


FIGURE 8a. **Bathymetric map of Ridinger Lake at Tributary #1. (Scale 1:5383)**

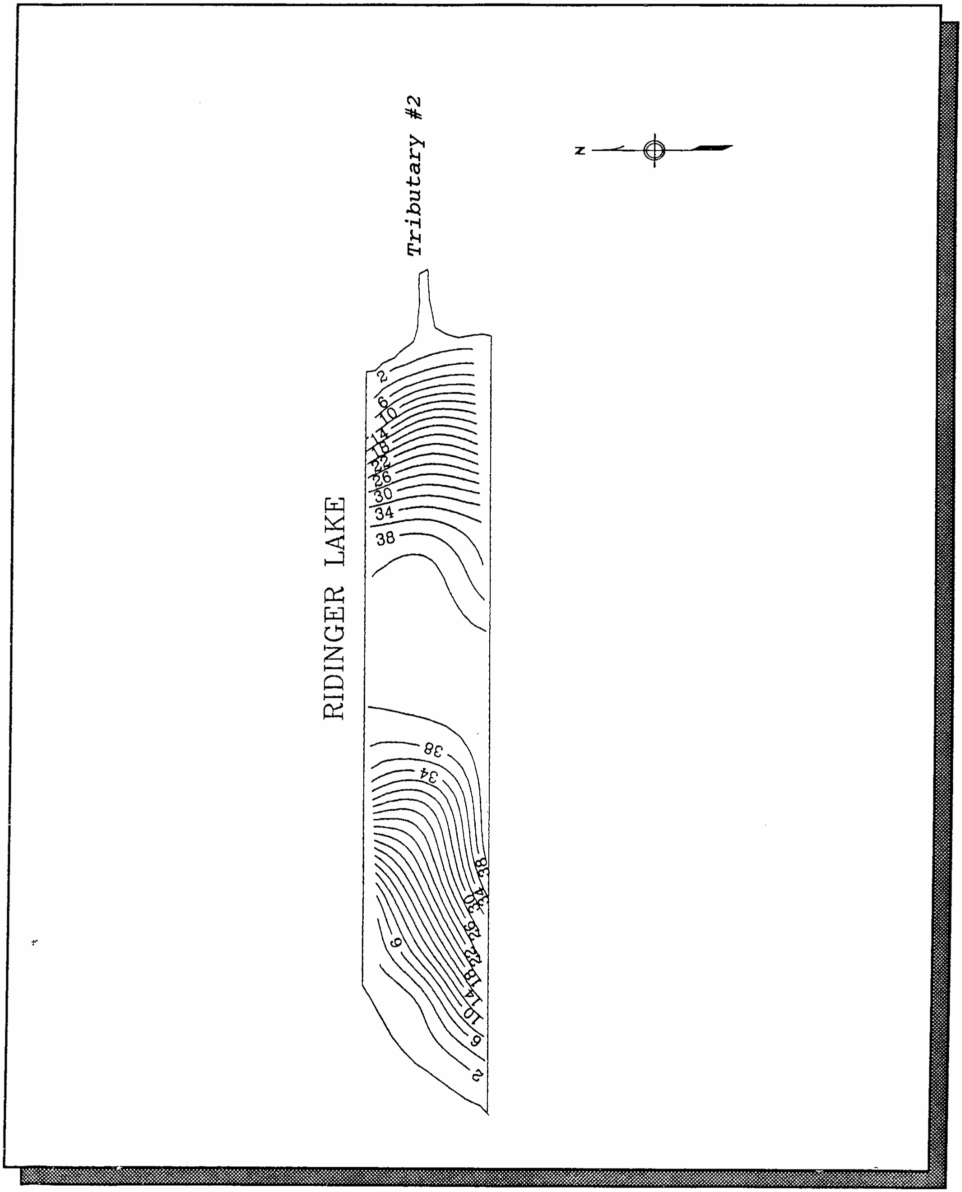


FIGURE 8b. Bathymetric map of Ridinger Lake at Tributary #2. (Scale 1:8,077)

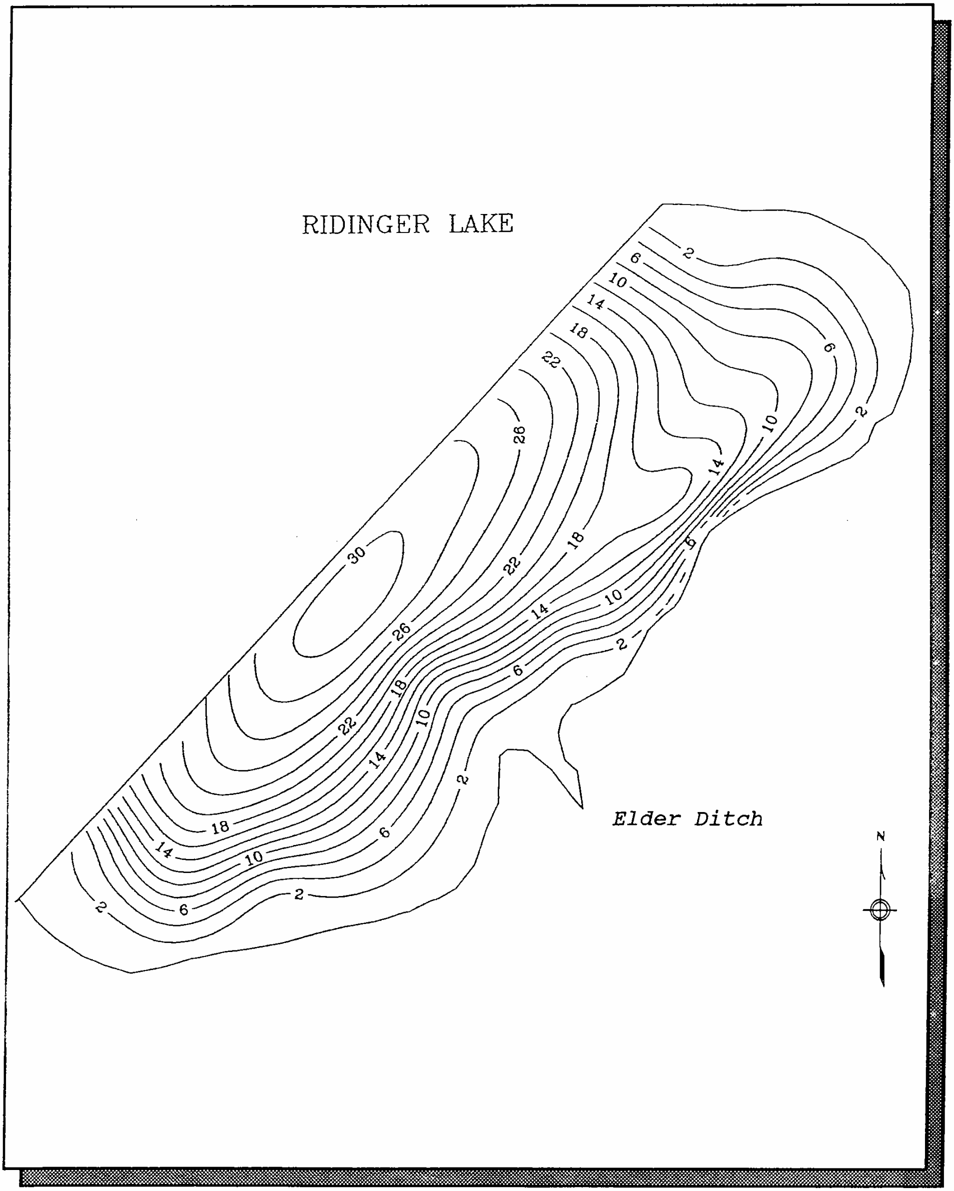


FIGURE 8c. Bathymetric map of Ridinger Lake at Elder Ditch. (Scale 1:5,719)

sedimentation for the three tributaries as a whole is 0.32 inches per year. This rate must be viewed as a conservative estimate because Elder Ditch has been dredged periodically over the last 20 years.

4.2 WATERSHED SURVEY

The watershed survey examined hydrology, land use, and erodible soils. The AGNPS model served as an important tool for integrating the effects of these factors on loading to the lake and interpreting their significance.

4.2.1 Hydrological Results

The principal hydrologic parameter of interest in developing a restoration strategy for Ridinger Lake is the hydraulic residence time, defined as the length of time required for the entire volume of the lake to be replaced with "new" water from runoff and direct precipitation. This parameter defines how dynamic the system is and how responsive a lake will be to changes in nutrient loading.

For this study, hydraulic residence time was computed as the ratio of lake water volume to the net annual inflow water volume. The formula used in calculating retention time (τ) is as follows:

$$\tau = \frac{V}{R+P-E}$$

Where:

τ = Hydraulic retention time (years)

V = Lake volume (acre feet)

E = Evaporative losses (acre feet/year)

P = Precipitation (acre feet/year)

R = Average annual runoff (acre feet/year)

Average annual runoff for the Ridinger Lake watershed was determined by multiplying the watershed area by the average annual runoff value of 12.38 inches (1.03 feet) reported for the Tippecanoe River at Oswego, IN (USGS, 1988).

Average annual rainfall for the Kosciusko and Whitley County area of Indiana is 36 in/yr (USGS, 1988). Thus, direct rainfall input to the lake was estimated to be 408 acre-feet per year. Evaporative losses from the lake surfaces in northern Indiana are approximately 32 inches/year (Geraghty et. al., 1973), or approximately 363 acre-feet for Ridinger Lake. Thus, there is a net increase of four inches (0.33 feet), or approximately 45 acre-feet of water added to the lake annually (i.e., the difference between direct precipitation input and evaporative losses).

The hydraulic residence time for Ridinger Lake was calculated to be 0.13 years (47 days), a relatively short retention period. Based on this calculation (i.e., 0.13 years), the entire volume of the lake would be replaced at several times during the growing season. During summer stratification, however, flushing of the lake is incomplete. Due to greater density, the colder bottom waters are not subject to frequent flushing and remain in contact with the sediments until stratification weakens and fall turnover begins. Thus, the residence time of the surface (epilimnetic) waters, which occupy a smaller percentage of the lake volume, is shorter than the residence time calculated for the entire lake volume.

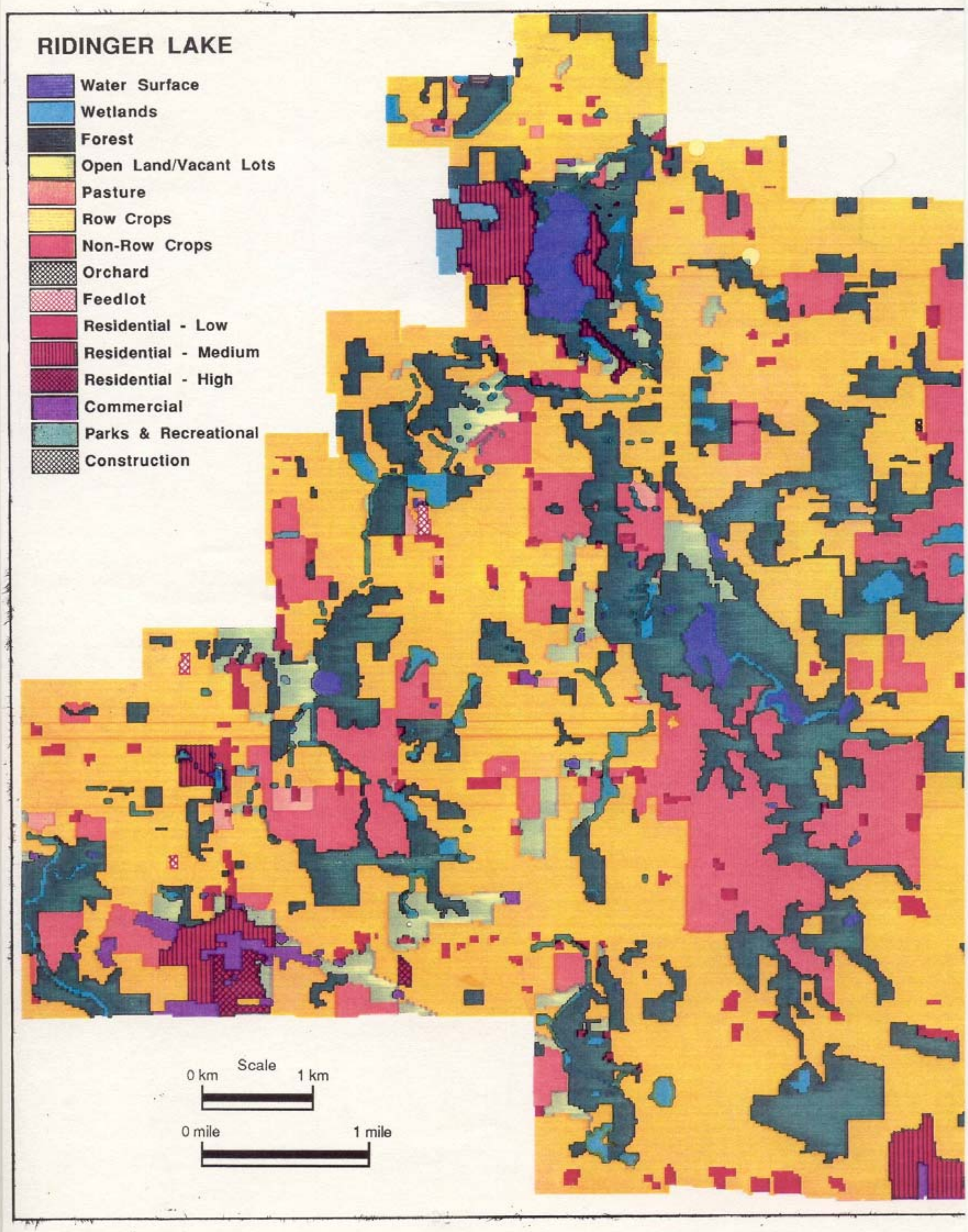
From the perspective of lake restoration, Ridinger Lake is likely to have a relatively rapid response to a reduction in external nutrient loading based on the short retention time. Moreover, after de-stratification, the accumulated sediment nutrients will be subject to reduction by flushing effects as released nutrients are washed out of the system.

4.2.2 Land Use Characterization

One of the most influential factors governing the quality of a surface water body is the nature of land use in the drainage basin. Land use characterization within the Ridinger Lake watershed was critical in determining the input parameters for the AGNPS model. A land use map is presented in Figure 9. The different land use categories and corresponding percentages of areal coverage are listed in Table 19.

The primary land use within the Ridinger Lake watershed was row crop agriculture, accounting for 57.7% of the total area. Blocks of row crops were found uniformly dispersed throughout the entire basin. Forested land constituted 19.1% of the watershed area and was found throughout the drainage basin, with higher densities located along the Elder Ditch corridor. Non-row crop agriculture comprised the third highest percentage of land use (11.8%), and was also found throughout the watershed. Row crop and non-row crop agriculture together comprised 69.5% of the watershed area and, as such, presented the most significant potential source of sediment and nutrient loading to Ridinger Lake.

The three residential use categories together accounted for only 4.3% of the watershed area, with larger concentrations occurring in the town of Pierceton and along the west shore of the lake. The immediate shoreline of Ridinger Lake is characterized by forested land with medium density residential areas located along the west and east shores and the Elder Ditch inflow.


RIDINGER LAKE
Water Surface
Wetlands
Forest
Open Land/Vacant Lots
Pasture
Row Crops
Non-Row Crops
Orchard
Feedlot
Residential - Low
Residential - Medium
Residential - High
Commercial
Parks & Recreational
Construction
Scale
0 km
1 km
0 mile
1 mile

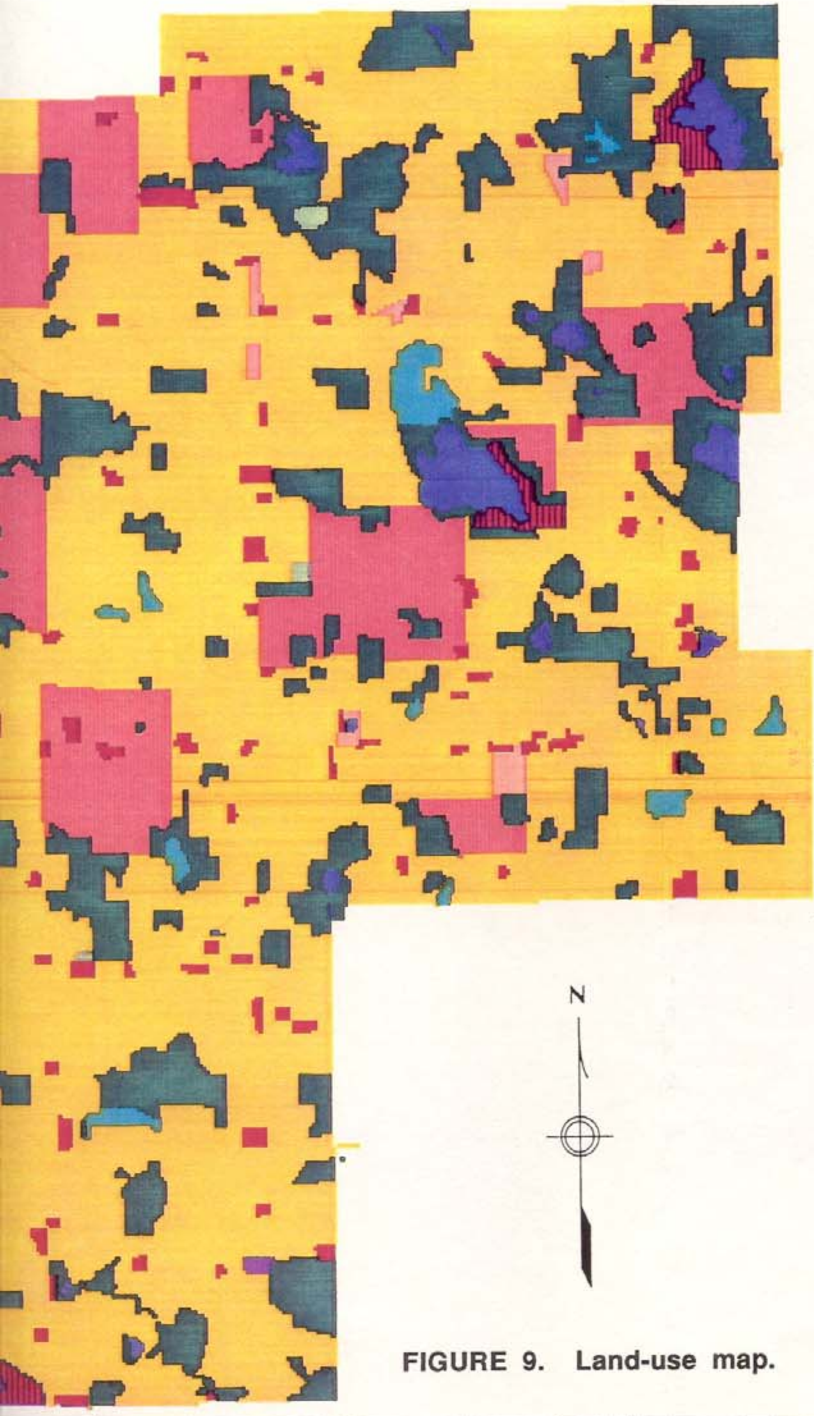


FIGURE 9. Land-use map.

TABLE 19. Land use in the Ridinger Lake Watershed.

WATERSHED CATEGORY	PERCENT
Water	1.6
Wetlands	1.8
Forest	19.1
Open	2.4
Pasture	0.6
Row Crops	57.7
Non-row Crops	11.8
Orchards	0.0
Feedlots	0.1
Low Density Residential	2.3
Medium Density Residential	1.8
High Density Residential	0.2
Commercial	0.4
Institutional	0.2
Bare/Unseeded Ground	0.0
Resource Extraction	0.0

4.2.3 Erodible Soil Evaluation

The "Northeast Indiana Erosion Study" (Kosciusko County Soil and Water Conservation District, 1987 and Whitley Co. Soil and Water Conservation District, 1987) cited loss of soil productivity, prevention of small plant growth, and contribution of soil to ditches as three primary problems associated with soil erosion. The study identified major erosion problem areas, and rates of erosion in 14 counties in northeastern Indiana, including Kosciusko and Whitley Counties. Problem areas are defined in the reports as areas "with a predominance of land that is eroding substantially in excess of rates at which it will maintain its' productivity". The results of the USDA report were used to identify problem areas in the Ridinger Lake watershed. A digital planimeter was used to determine the portion of the watershed area containing highly erodible soils.

The USDA estimate of soil erosion in Kosciusko County was 10.9 tons/acre/year (291 yd^3/acre/year): 5.8 tons (155 yd^3) from sheet and rill erosion, 3.1 tons (83 yd^3) from wind, and one ton (27 yd^3) from gully erosion. The Shanton Ditch portion of the watershed would therefore contribute approximately 30,000 tons (800,000 yd^3) of sediment per year.

Of 13,426 acres in the Whitley County portion of the watershed, 9,801 acres (73 %) were found to be major erosion problem areas. The USDA study estimated a higher rate of erosion in Whitley than in Kosciusko County. An overall rate of 18.7 tons/acre/year (i.e., 499 yd^3/acre/year) was estimated for problem areas in Whitley County: 14.0 tons (373 yd^3) from sheet and rill erosion, 0.4 tons (11 yd^3) from wind erosion, and 4.3 tons (115 yd^3) from gully erosion . The 9,801 acres of problem area land in Whitley County would produce approximately 183,000 tons (i.e., 4,880,000 yd^3) of sediment per year. This is roughly six times the rate calculated for the Kosciusko County portion.

In a preliminary investigation of Kosciusko County lakes, Hippensteel (1989) evaluated erodible soils in the Kosciusko County portion of the Ridinger Lake watershed. This study identified specific highly erodible soil types and their location, rather than the more broadly defined problem areas in the USDA study. A total of 1,426 acres (29%) of the Ridinger Lake watershed within Kosciusko County were found to contain highly erodible soil types. Of 4,900 acres in the Shanton Ditch portion of the watershed, 2,744 acres (56%) were found to contain erodible soil types (Hippensteel, 1989).

4.2.4 Sediment and Nutrient Modeling

Prior to running the AGNPS model, it was necessary to divide the watershed into a grid of equal areas, called "cells". This grid was prepared by quartering each 640 acre section of the USGS 1:24,000 topographic map, creating eight 80 acre cells. These cells were then further subdivided to yield 16 40 acre cells per section. This method allowed referencing of cells to Range and Township boundaries. In cells bordering Ridinger Lake, and in cells with average slopes greater than 10%, the 40 acre cells were divided into four 10 acre cells to provide greater resolution. Cells identified during preliminary runs of the model with high rates of erosion were also subdivided into 10 acre cells. The AGNPS cell grid for the Ridinger Lake watershed contains 546 40-acre cells (Figure 10).

Data characterizing the physical features of the cells were utilized by the model to estimate the sediment and nutrient contributions of each cell. These estimates were used to identify cells that were responsible for disproportionately high sediment and nutrient loading. Four categories of AGNPS output were evaluated in describing the pertinent export features: (1) sediment yield; (2) cell erosion; (3) nutrient loading; and (4) hydrology. The AGNPS model was run on one distinct scenario: a U. S. Weather Bureau defined, type two, two-year, 24-hour storm during the Spring growing season.

Sediment Yield and Erosion

Sediment yield from each AGNPS cell is the amount of sediment, in tons, that leaves a cell at its downstream edge. This yield represents not only the sediment generated inside the cell but also the sediment generated upstream and sediment deposition within the cell. Therefore, sediment yield is calculated as the sediment generated within the cell, plus upstream contributions, minus deposition.

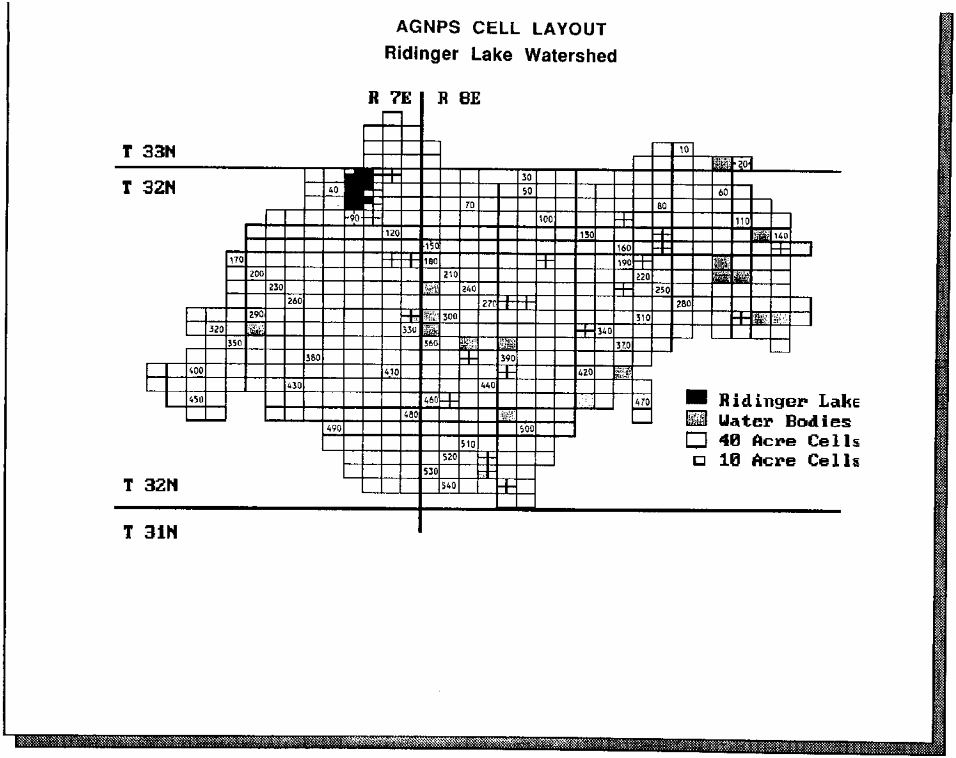


FIGURE 10. AGNPS cell layout of Ridinger Lake watershed.

Cell erosion refers to the amount of sediment that is produced by the storm event within an individual cell rather than the cumulative amount passing through the cell. It is useful in identifying the cells that experience the greatest amount of internal erosion. The most important factors contributing to erosion within a given cell are soil erodibility (i.e., K-factor) and land slope. Land use, water flow velocity, and the presence/absence of agriculture or unmitigated construction generally produce higher erosion losses than areas consisting of forests or wetlands. Watershed cells with comparatively high sediment yield and cell erosion are displayed in Figures 11 and 12, respectively.

The AGNPS model results indicated that the greatest sediment yield in the watershed occurred within the Elder Ditch drainage basin. Elder Ditch enters Ridinger Lake in the southwest corner of cell #65 (Cell # 65-003). This cell yielded 5,418 tons of sediment during the 24 hour simulated storm, 98% of the total sediment yield to the lake. A large portion of this yield (3,514 tons) was contributed to Elder Ditch by the Cedar Lake Branch, which drains 10,040 acres in the northeastern portion of the watershed. This part of the watershed is almost exclusively in Whitley County. The dominant land use within this area is row crop agriculture.

The sediment yield from the northeast tributary, draining 400 acres, was 51 tons. The yield from the east tributary, draining 140 acres, was 12 tons. As expected, the sediment yield from these two subbasins was much smaller than from Elder Ditch.

The maximum cell erosion observed during the modeled storm was 25 tons/acre. The average value for all cells was 3.1 tons/acre. As indicated in Figure 12, cells indicating excessive erosion (greater than 10 tons/acre) were generally confined to the eastern two-thirds of the watershed. Erosion in excess of 20 tons/acre was observed in Cell #209, a 40 acre cell, and in Cells #339-002, #522-002, and #461-003. Two of these cells contain stream channels. Cell 209 contains a section of White Branch Ditch, which joins Elder Ditch in the next cell west (#208) at the intersection of Old Highway 30 and the County line. Cell #522-002 is the upper right (northeast) 10 acre section of Cell 522. This cell contains a section of Mathias Ditch just north of its headwaters in the southern portion of the watershed. Mathias Ditch is the primary tributary to Rine Lake.

In general, cells with erosion equal to or greater than 10 tons per acre or greater had slopes of 10-15%, soil erodibility factors of approximately 0.4, and agricultural land use. Because high erosion factors and extensive agriculture occur throughout the entire watershed, higher land slopes in the Whitley County portion of the watershed are the likely cause of higher erosion in this area.

The impact of excessive erosion in cells located just east of the county border in the southern portion of the watershed was greatly reduced by the Rine/Robinson Lake system. Of 1,168 tons of sediment yielded to Rine Lake, less than 1 ton exits Robinson Lake. Other lakes in the watershed, such as Pierceton, Scott, and Troy Cedar, would also be expected to act as sediment traps within the Elder Ditch drainage basin. These lakes drain a total of 3,640 acres, 17% of the total watershed acreage.

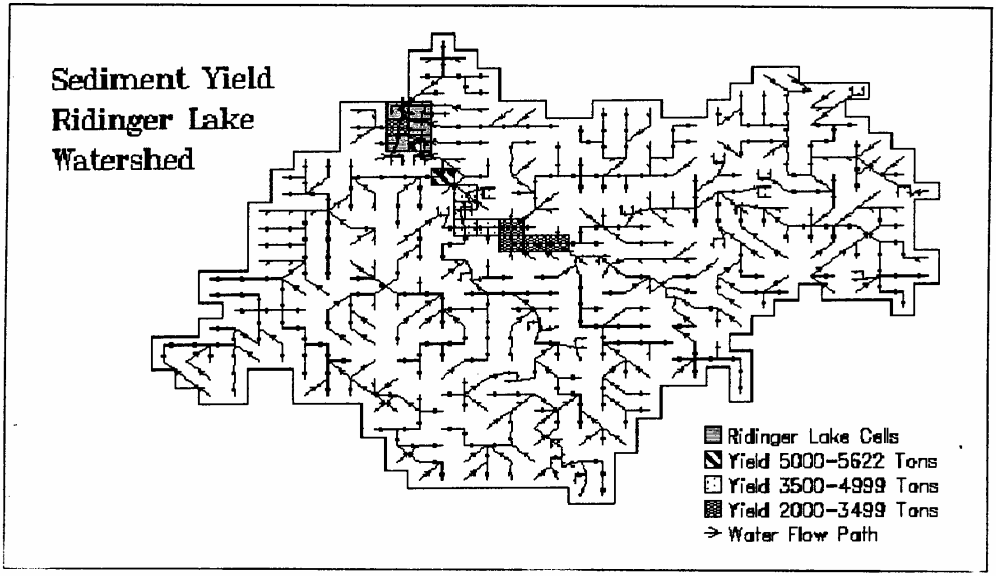


FIGURE 11. Sediment yield for Ridinger Lake watershed.

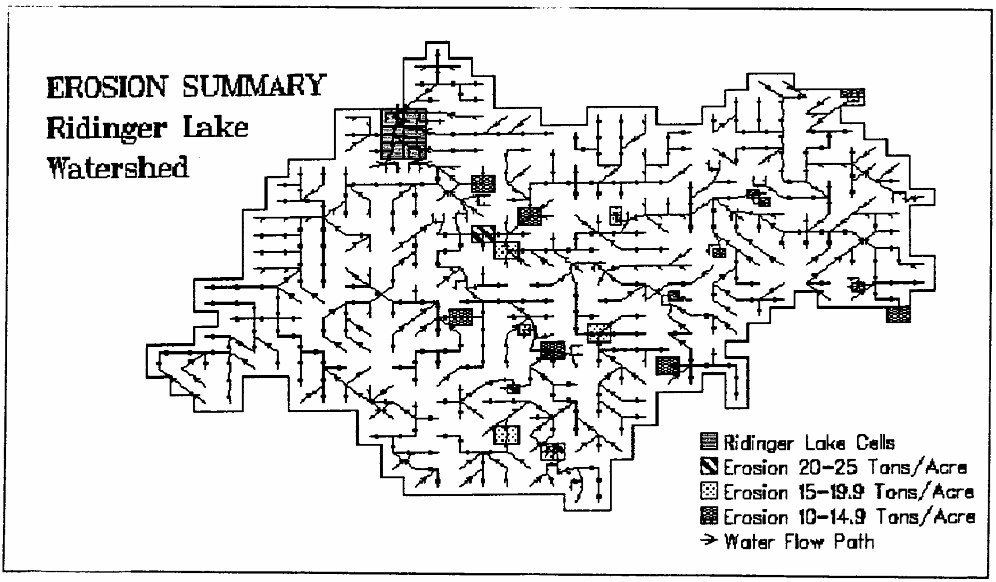


FIGURE 12. Erosion summary for Ridinger Lake watershed.

Nutrient Loading

The AGNPS model supplied estimates for both soluble and sediment nitrogen and phosphorus concentrations in runoff from the watershed. Soluble forms of both nutrients are readily available to aquatic vegetation and phytoplankton, whereas the sediment bound fractions are not likely to have an immediate biological effect. From estimates of both nutrient fractions, nitrogen and phosphorus loadings could be calculated. The AGNPS model furnished predictions for the entire watershed and for individual cells.

Nitrogen Loading:

Using cumulative data generated by the AGNPS model it was possible to calculate cell yield of total nitrogen (both soluble N and sediment-bound N) during the design storm from each of the three tributaries. Areas of excessive sediment bound nitrogen loading and soluble nitrogen loading were in the southern and eastern portions of the watershed (Figure 13). Sediment nitrogen for the entire watershed ranged from 0.0 to 36 pounds/acre. Soluble nitrogen ranged from 0.0 to seven pounds/acre. The loading for the entire Elder Ditch watershed was 3.75 pounds/acre. Based on the per acre loading rates for the three tributaries to the lake, the contribution from Elder Ditch far exceeded that of the other two tributaries. Loadings of 388 pounds, 286 pounds, and 75,488 pounds were calculated for the northeast, east, and Elder Ditch tributaries, respectively. An additional 1,989 pounds of nitrogen loading occurring from overland runoff was received from lands adjacent to the lake. These lands include Jellystone Park, and the residential areas on the west, southwest, and southeast shores of Ridinger Lake.

A large portion of the nitrogen loading from Elder Ditch originated from the Troy Cedar Branch. The Troy Cedar Branch, which enters Elder Ditch at cell 209, contributed 44,076 pounds of N to Elder Ditch (4.39 pounds/acre). Because much of the nitrogen loading from the southern portion of the watershed was intercepted by the Rine/Robinson Lake system in the south and Troy Cedar Lake in the east, cells having the greatest impact on water quality on Ridinger Lake would be those that drain the area from Troy Cedar Lake's outlet, west to Elder Ditch. This area, occupying 8,000 acres, added a total 36,880 pounds of nitrogen, or 4.61 pounds per acre, to Elder Ditch. The loading from this area was approximately 30% greater per acre than the 2,040 acre Troy Cedar Lake watershed.

Between the Troy Cedar Lake outlet and Elder Ditch, three cells had sediment nitrogen values in excess of 15 pounds per acre (Figure 13). The 10 acre cell #186-300 generated 32.4 pounds/acre sediment nitrogen. Ten acre cells 162-100 and 162-400 produced 26.1 pounds/acre. Cell 186-300 is located 1/4 mile west of CR 650 West and is dissected by Troy Cedar Branch. Cells 162-100 and 162-400 are approximately 1/4 mile north of Troy Cedar Branch. The western border of 162-100 is CR 550 West. Cell 162-400 is 1/8 mile southeast of Cell 162-100.

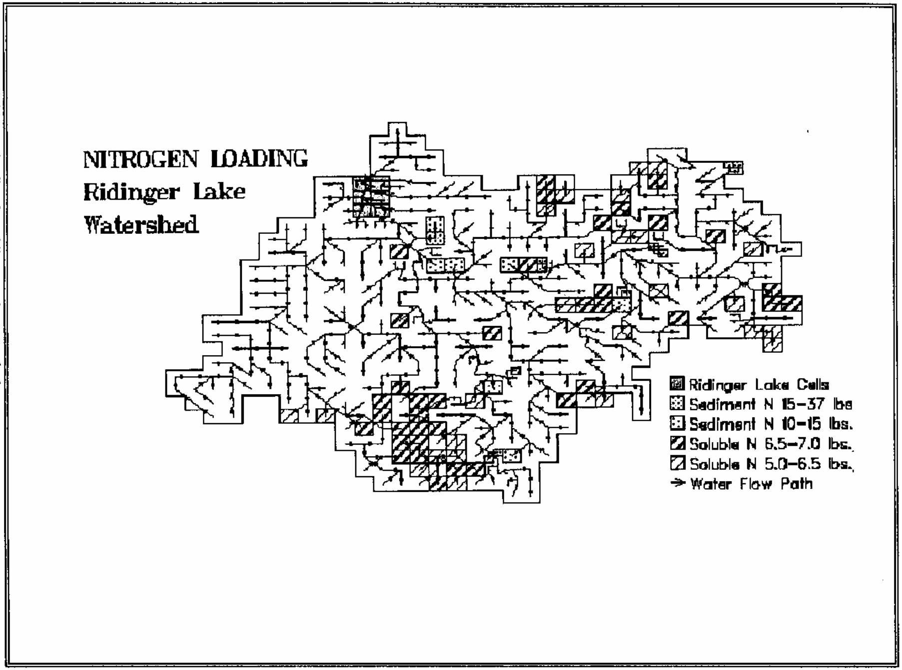


FIGURE 13. Nitrogen loading for Ridinger Lake watershed.

Other cells outside the Troy Cedar Branch sub-basin generated excessive amounts of sediment N. Cells 122 and 445 generated 31.3 and 25.9 pounds/acre, respectively. The western border of cell 122, located one mile north of Old Road 30, is the county line. The west border of cell 445 is CR 650 West and the south border is CR 300 North. Other cells in the Elder Ditch watershed generated sediment N greater than 15 pounds/acre, however, loading from these cells was intercepted by water bodies upstream of Ridinger Lake.

Cells generating the highest soluble N (between 6.5 and 7.0 pounds/acre) were concentrated near the county border in the southern part of the watershed. These cells were generally confined to an area approximately two miles east of the center of Pierceton to one mile west of Larwill. High soluble N loading was also observed in isolated cells in the western part of the watershed. The majority of these cells resided in the Troy Cedar Branch sub-basin. Cells within this sub-basin contributing greater than 6.5 pounds of soluble N were numbers 31, 51, 103, 181, 184, 185, 247, 275, and 276. Six of these cells, 31, 51, 103, 247, 275, and 276, were located in poorly drained soils, minimizing nitrogen transport to Troy Cedar Branch. The remaining cells, 181, 184, and 185 transported the largest amounts of soluble N to Troy Cedar Branch. Cell 181 is located near the intersection of CR 550 North and Elder Road. Cells 184 and 185 are located approximately 1/2 to 3/4 of a mile west of CR 650 W just north of Troy Cedar Branch. Cell 148, located outside the Troy Cedar sub-basin and within one mile of Ridinger Lake, generated 6.97 pounds/acre of soluble N, and drains directly into Elder Ditch. This cell is located 3/8 mile due south of the confluence of Shanton and Elder Ditch.

Phosphorus Loading:

Cells generating excessive soluble phosphorus loadings and sediment-bound phosphorus loadings (Figure 14) were generally confined to the southern and eastern portions of the watershed (Figure 14). Within cell sediment phosphorus loading rates ranged from 0.0 to 10 pounds/acre. Soluble phosphorus generated within cells ranged from 0.0 to 1.5 pounds/acre. Total phosphorus loadings (both soluble P and sediment bound P) of 136 pounds, 74 pounds, and 22,143 pounds were calculated for the northeast, east, and Elder Ditch tributaries, respectively. An additional 618 pounds of phosphorus loading was contributed from lands adjacent to the lake. A large portion of the phosphorus loading originated from Troy Cedar Branch.

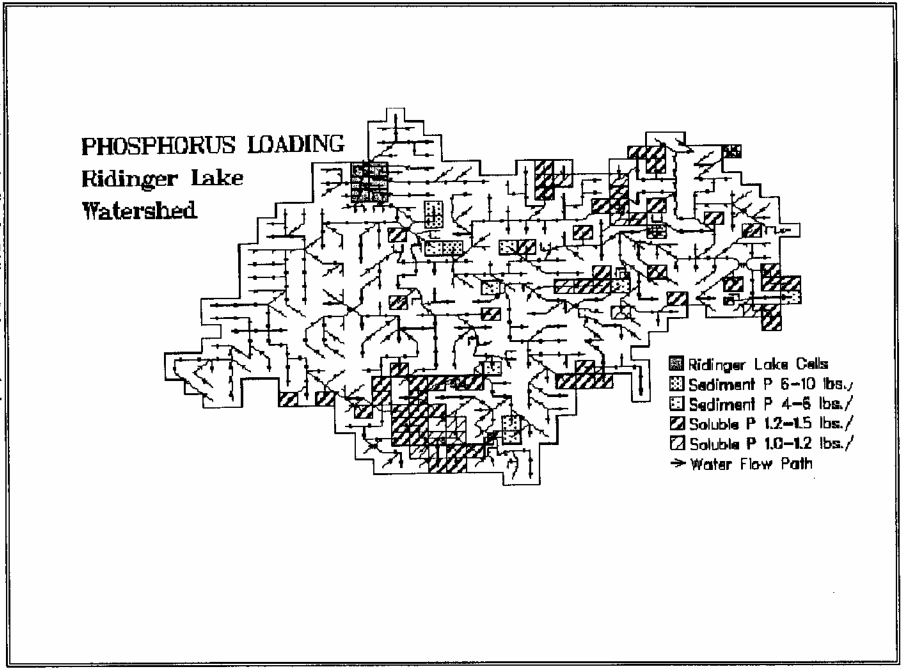


FIGURE 14. Phosphorus loading for Ridinger Lake watershed.

The Troy Cedar Branch sub-basin was characterized by a total P loading of 1.33 pounds/acre. This value compares with a total P loading of 1.10 pounds/acre for the entire Elder Ditch sub-basin. Within the Troy Cedar Branch sub-basin, cells 167, 181, 373, 445, 469, and the southeast corner of 162 (162-400) all generated sediment P in excess of six pounds/acre. Cell 181 yielded 6.51 pounds/acre; cell 373, 11.29 pounds/acre; cell 445, 8.98 pounds/acre; cell 469, 6.14 pounds acre; cell 167 6.03 pounds/acre; and 162-400, 10.11 pounds/acre. Sediment P generated from cell 167 would be expected to be deposited in Troy Cedar Lake. Runoff from the remaining cells encounters no water bodies in route to Ridinger Lake. Cells 181, 445, and 162-400 have already been identified as N contributors. Cell 469 is located immediately south of CR 300 North, 1/4 mile east of CR 650 West. Cell 373 is located immediately south of CR 400 North, approximately 1/4-1/2 mile west of CR 350 West. Cell 469 is located immediately south of CR 300 North, approximately 1/4-1/2 mile east of CR 650 West.

Cells where soluble P was generated in excess of 1.2 pounds/acre were concentrated in the same area mentioned above: the southern part of the watershed, west of Larwill. Most of these cells are within the Troy Cedar Branch sub-basin. Two of these cells, 158 and 185, have short drainage paths to Troy Cedar Branch. Cell 158 is located 1/4 mile north of Troy Cedar Branch, immediately east of CR 650 West. Cell 185 was also identified as a contributor of high sediment N. Cell 148 generated 1.46 pounds/acre of soluble P, and drains directly into Elder Ditch. This cell is located 3/8 mile due south of the confluence of Shanton and Elder Ditch.

SECTION 5. SEDIMENT AND NUTRIENT CONTROL TECHNOLOGIES

Based on the results of the watershed analysis, storm sampling, and bathymetric data, the main source of sediment and nutrients to Ridinger Lake is through the Elder Ditch tributary system, primarily the Troy Cedar Branch sub-basin. The AGNPS model identified problem cells within this drainage, however, Ridinger Lake is impacted by non-point source pollution (i.e., diffuse inputs of nutrients and sediments). As such, increased eutrophication in the lake cannot be tied to specific causal agents or sources. Agricultural activities in the upland areas, potential septic leachate from lakeshore residences, and fertilizer and animal waste runoff are all likely to impact the lake in varying degrees. These problems require the widespread application of best management practices (BMP's) within the watershed. The following section is a discussion of the types of BMP's that would be expected to have the greatest role in reducing nutrient concentrations and sediment inputs to the lake and receiving streams. Section 5.1 focuses on erosion control techniques that will reduce both nutrient and sediment transport to streams. The techniques described are primarily aimed at reducing loading from agricultural areas, however urban erosion control is also discussed. Section 5.2 provides an overview of BMP's for nutrient reduction specific to agricultural areas. This section also includes recommended maintenance procedures applicable to the Jellystone Park Campground. Section 5.3 describes applicable in-lake restoration strategies.

5.1 EROSION CONTROL

This section provides an overview of agricultural BMP's that have been developed for erosion control on cropland, pastures, streambanks, and animal waste activities within agricultural watersheds. Although not classified as lake restoration techniques, these practices maintain productivity on the land, reduce costs of fertilizers and pesticides, and ultimately benefit receiving streams and lakes. BMP's for septic systems and applicable urban BMP's, such as those designed to reduce erosion and runoff on construction sites, are also described. However, it was beyond the scope of this study to describe these practices in detail. The Soil Conservation Service has published design criteria for a variety of BMP's, including those discussed below. This agency has and will continue to provide guidance to individual farmers and land owners in selection and implementation of BMP's. The following summary is drawn from a number of services, including manual developed by the EPA, in conjunction with the North American Lake Management Society, entitled Lake and Reservoir Restoration Guidance Manual; and documents published by the Hoosier Heartland Resource Conservation and Development Council.

5.1.1 Agricultural Erosion Control

Conservation Tillage

Erosion in agricultural areas of the watershed can be significantly reduced by conservation tillage practices. The objective of this type of BMP is to protect the soil from wind and water erosion by increasing the amount of crop residue. No till farming, where the topsoil is left essentially undisturbed year round, and minimum tillage are forms of this BMP. Some form of conservation tillage is currently practiced on 17% of major erosion problem areas (MEPAS) in Whitley County, and 35% of these areas in Kosciusko County (Northeast IN Erosion Study, 1987). The effectiveness of these practices in reducing sediment loss and runoff is considered fair to excellent, depending on the degree of tillage reduction (USEPA, 1988). Phosphorus in runoff can be greatly reduced with conservation tillage, however nitrogen concentrations are largely unaffected. In fact, total nitrogen and herbicide concentrations may increase in groundwater as a result of no till practices, a potential negative side effect. Fertilizer management and integrated pesticide management should accompany conservation tillage practices.

Contour Farming/Stripcropping

Contour plowing and contour stripcropping are effective in reducing soil loss on farm land with a 2-8 percent, and 8-15 percent slope, respectively. Both practices require plowing along the natural contours. In stripcropping, grasses or other close growing crops are planted between row crops, such as corn or soybeans.

Streamside Management/Buffer Strips

Vegetation planted between a stream and plowed field (a buffer strip) is extremely effective in reducing both nutrient and sediment inputs, and in protecting riparian habitat. In addition, butter strips have been shown to enhance biological resources in streams (IS&T, 1990). This is a very cost effective practice. Once established a buffer strip will maintain itself indefinitely. Parameters that determine the effectiveness of filter strips include filter width, slope, vegetation type, and application rate of fertilizers.

Other Erosion Control Practices

Management of pasture lands to prevent overgrazing, thereby reducing soil compaction and runoff, is important in an overall sedimentation control plan. Stream banks should be fenced to prevent access to cattle and destruction of soft banks. Crop rotation, terracing, and soil stabilization are also effective in reducing sediment inputs to streams.

5.1.2 Urban/Residential Erosion Control

Control of erosion due to development or construction activities must be a component of a watershed wide approach to reduce sedimentation in Ridinger Lake. Factors that influence the type and amount of erosion include the nature and extent of vegetative cover, topography; and the frequency, and intensity of rainfall events.

Vegetative cover plays a critical role in controlling erosion by absorbing the impact of falling rain, holding soils together, increasing the retention capacity of soils, and slowing runoff velocity. Evapotranspiration by plant cover also aids in reducing erosion by removing water from soils between rainfall events.

Topographic characteristics (i.e., slope, size, and shape) of the drainage basin have a strong influence on the amount and rate of runoff. Large drainage basins, such as the Ridinger Lake watershed, produce higher flows and volume of runoff than do smaller basins. Thus, changes to site topography resulting from development can have a significant impact on the quantity of runoff, and therefore sediment, that is generated.

The characteristics of surface and subsurface soils are fundamental to the resistance of soils to erosive forces, and to the nature of the sediment that results from erosion. Soils with high sand and silt content are normally the most highly erodible. Increasing organic and clay content result in decreased erodibility, however these soils are more easily transported.

In general, the following practices may be applied to control of erosion due to land development activities within the Ridinger Lake watershed. These practices are not presented in detail. An excellent source of further information specific to Indiana is the Hoosier Heartland Resource Conservation and Development Council's Urban Development Planning Guide (HHRCDC, 1985). This group, in combination with municipal and state agency personnel, has also published a model erosion control ordinance (HERPIC, 1989) that may be used at both the City and County levels.

Phased Construction. Phasing construction activities minimizes the extent of land disrupted at one time, reducing the sediment load to a receiving stream or lake during a given storm event. If multiple structures are to be built over an extended period, the entire area slated for development may not have to be cleared at once.

Road Stabilization: Several practices are available to minimize erosion and sediment transport due to traffic in construction areas. These include stabilization of freshly graded road surfaces with gravel and installation of gravel pads at entrances to construction sites. The latter serve to reduce the amount of sediment carried off-site on tires of construction vehicles.

Sediment Barriers: Various types of barriers may be placed in the path of runoff to detain sediment and decrease flow velocities. These barriers, consisting of hay or geotextile filter fabric, are placed across or at the toe of slopes. Sediment barriers are also effective in protecting storm drain inlets from construction site runoff.

Sediment Traps and Basins: Temporary basins may be constructed to contain flows long enough for sediment to settle out. These basins are characteristically simple, often consisting of a small pond formed by an earthen dike, with a gravel lined outlet.

Establishment of Vegetative Cover: Planting of fast growing grasses and other plants provides a means for quickly stabilizing disturbed areas. The choice of plant type will depend on the intended permanency of the cover. Mulching with straw and other fibrous materials will aid in establishment of protective vegetation. This in itself will reduce erosion and runoff on disturbed areas.

For future developments in the Ridinger Lake Watershed, an erosion and sediment control plan should be developed to address the potential problems resulting from the particular activity. The plan should clearly present the anticipated erosion and sedimentation problems that are likely to result, and the measures that will be taken to mitigate them. Both narrative and graphical sections should be included. The narrative section should include the following:

- Brief description of the project
- Existing conditions (physical features, slope, etc.)
- Description of adjacent areas that may be impacted
- Summary of soil characteristics
- Identification of problem areas (high slope, erodible soils, etc.)
- Erosion and sediment control measures to be used
- Description of post construction stabilization and practices, including measures to control storm water runoff
- Storm water runoff concerns and impacts
- Inspection and maintenance schedules planned
- Calculations used in design of basins, waterways, and other structural controls

Graphical materials in the site plan should provide the necessary maps and related materials, including:

- Vicinity map showing site location
- Current elevation contours
- Existing vegetation types and locations
- Soils
- Critical erosion areas
- Existing drainage patterns
- Proposed contours after grading
- Limits of clearing and grading
- Location of erosion and sediment control practices
- Detailed drawings of structural practices to be used

The final plan should be subject to approval of a county or local planning board or similar group, and should provide comprehensive documentation of the erosion and sediment control strategies to be applied in the development of the site.

5.2 WATERSHED NUTRIENT REDUCTION

The control of nutrients from agricultural activities must be given top priority as a management objective for the Ridinger Lake watershed. In addition to causing nuisance algae and other water quality problems in the lake, excessive nutrient loading can result in groundwater contamination and human health effects. Animal wastes and fertilizers are two key sources of nutrients in the watershed. The techniques mentioned in Section 5.1.1 concerning agricultural erosion control will also result in reduction of sediment bound forms of nutrients. As such, the section below focuses on BMP's designed specifically to reduce soluble inputs. Animal wastes from feedlots and confinement areas, application of animal manures as fertilizers, and commercial fertilizers themselves are primary sources of soluble nitrogen and phosphorus. BMP's for pasture management and stream protection are also described.

5.2.1 Animal Production and Keeping

The need for confinement of animals in feed lots or holding facilities, as opposed to open pastures, results in highly concentrated runoff. Summaries of several BMP's that have been designed to address problems associated with confinement areas are presented below.

(1) Roofing: The Ridinger Lake watershed receives approximately three feet of rainfall per year. This means that for each acre of open confinement area, over a million gallons of contaminated water are generated on an annual basis. Washdown water may equal this amount. Roofing confinement areas allows separation of clean runoff from contaminated slab runoff. Roof gutters and a water collection system greatly reduce the amount of water that must be treated.

(2) Location: The amount of pollutants entering a stream decreases with distance from the source. The distance where zero pollution enters a waterway has been estimated to be 98 to 393 feet, depending on soil characteristics, grass type, and density of cover (Novotny, 1981). Confinement areas should be built up and graded away from a ditch or stream. Animals should be fenced no closer than the top of the grade. The ditch slope should have a grass cover, and the runoff from the storage facility should be retained.

(3) Washdown Water: BMP's for the use of washdown water focus on recycling and reduction in the quantity of water used. Substituting higher water pressure for volume and scraping manure prior to hosing minimizes water usage.

(4) Manure Storage Lagoons: Farms with a limited capacity for liquid manure storage must frequently spread the lagoon contents on pasture land to prevent overflow. This often results in ponding of the liquid waste during periods when the ground is saturated (e.g., following snowmelt in the spring). Manure applied under these conditions is likely to flow off of the field and into a waterway. Installation of a solids separator ahead of the lagoon increases the capacity of the lagoon and lengthens the period between cleaning. In addition, odor problems are reduced.

5.2.2 Manure Application to Pastures

Although no data are available for the Ridinger Lake watershed, it is probable that a large percentage of manure that is produced from animal production is returned to the land. There is general agreement that manure can and should be used in crop production to increase yields and fertility. However, water quality degradation will occur without proper management of manure application. Proper timing of application (i.e., during non-saturated conditions), application to land with minimal slope, addition of manure in quantities equal to crop requirements, and avoidance of soil compaction during the application process will minimize problems due to manure application.

5.2.3 Fertilizer Management

Application of fertilizers in quantities equal to crop needs will greatly reduce nutrient enrichment of aquatic resources due to agricultural operations. Reducing the loss of nutrients to the groundwater or air is dependent on proper soil testing, and establishment of realistic yield goals. Knowledge of the contribution that legumes, manure, and crop rotation make to soil nitrogen and phosphorus levels is critical to determining proper application rates.

Over application of nitrogen has been recognized as a significant problem in agricultural areas throughout the country. Nitrate in soils in excess of crop requirements results in groundwater contamination, as well as increasing eutrophication of surface waters. Although some degree of over-application is necessary given significantly less than 100% uptake efficiencies, current research on this problem points to a lack of consideration of alternative sources of nitrogen, such as manure or alfalfa, in calculating the quantity of fertilizer necessary for a given yield (Granatstein, 1988). Nitrogen "credits" (i.e., a reduction in the amount of nitrogen necessary due to carryover from previous crops (legumes) or to crop rotation) result in both cost benefits to farmers and improved water quality. Examples of nitrogen credits, in terms of pounds/acre N for previous legume crops, are shown in Table 20. This information is taken from material published in a University of Wisconsin Extension Bulletin (Granatstein, 1988). The Kosciusko and Whitley County SCS can provide additional information on nitrogen management.

Table 20. Nitrogen credits for previous legume crops.

CROP	N CREDIT
Forages	
Alfalfa	40 lb. N/ac plus 1 lb. N/ac each percent legume in stand.
Red Clover	Use 80% of alfalfa credit.
Soybeans	1 lb. N/ac for each bu/ac of beans harvested up to a max. credit of 40lb. N/ac.
Green Manure Crops	
Sweet Clover	80-120 lb. N/ac.
Alfalfa	6-100 lb. N/ac.
Red Clover	50-80 lb. N/ac.
Vegetable Crops	
Peas, snapbeans, lima beans	10-20 lb. N/ac.

Phosphorus is not as mobile a nutrient as nitrogen, and will tend to remain in the soil for longer periods of time. Erosion will reduce soil phosphorus levels, however in many cases, phosphorus levels will have built up over the years, and continued, or "maintenance applications", may not be economically justified (Granatstein, 1988).

Timing of application is also a key factor in reducing the quantity of fertilizers that reach ground or surface waters. In general, application in the fall results in significant runoff and loss during the non-growing season. Spring pre-plant application is recommended.

5.2.4 Septic Systems

Homes on septic systems within the watershed, and more importantly, on the lakeshore, may be a source of nutrients. No data were collected during the Feasibility Study that indicated this, however a detailed septic system survey was beyond the scope of the project. The following paragraphs offer general guidance on installation, use, and maintenance of septic systems.

Proper Location: The features governing appropriate placement of septic systems include proper soils and adequate buffer distances between the drain field and sensitive areas. Information is available from both the SCS and USGS concerning the suitability of various soils and geologies for drain field construction. These agencies should be consulted prior to installing any new system. The Indiana Department of Environmental Management should also be contacted to determine the most recent limitations concerning minimum distance of the drain field from drinking supplies, lakes, drainage ditches, etc.

Regular Inspection and Maintenance: A septic tank should be inspected at least once per year to assess the rate of solids accumulation. If these materials build up, they will be transferred with the waste to the drain field, resulting in clogged soil pores. This condition results in a reduction of permeability, and eventually construction of a new drain field. Septic system maintenance should involve inspection of "Tee-joints" and distribution boxes, since these parts are especially prone to shifting that can lead to uneven dispersal of waste water into the drain field. Material removed from the tank should be discharged at a treatment plant. Periodic inspection and pumping will avoid this expense.

Drain Field Protection: Trees should not be allowed to grow on top of the drain field. Tree roots can penetrate the field, diminishing its efficiency. Vehicular traffic should also be prevented, since this will cause compaction of the leach field soils.

Proper Use: Solids, greases, or toxic materials should not be disposed of in septic systems. Solids, such as paper towels and disposable diapers, add to the overall load of the system, decreasing efficiency and increasing maintenance costs. Fats, oils, and greases can solidify in the system and create blockages. Toxic materials (e.g., paints, motor oil, pesticides) are not decomposed by septic systems and can leach out into groundwater, contaminating wells and eventually reaching lakes and streams. In addition, these materials can kill the beneficial bacteria responsible for decomposing normal septic system wastes.

Additives: Authorities agree that under most circumstances, chemical and biological additives are not needed to accelerate decomposition in the septic field. Under extreme use situations however, these additives may be helpful. Caution must be observed when using these products since some additives will actually inhibit decomposition. Products containing more than one percent of the following chemicals should not be used:

- **Halogenated hydrocarbons:** trichloroethane, trichloroethylene, methylene chloride, halogenated benzenes, carbon tetrachloride;
- **Aromatic hydrocarbons:** benzene, toluene, naphthalene;
- **Phenol derivatives:** trichlorophenol, pentachlorophenol, acrolein, acrylonitrile, benzidine.

A good reference with information on septic system design and maintenance is found in Perkins (1989).

5.2.5 Jellystone Park Grounds Maintenance

The following paragraphs provide a summary of maintenance procedures to reduce nutrient inputs to Ridinger Lake from the Jellystone Park facility. No data were collected during this study that indicated a problem specific to Jellystone Park, however, the following "common sense" procedures will minimize nutrient concentration in runoff from the Jellystone Park campground. Much of the material in this section is also applicable to homeowners.

<u>Grass and Leaves</u>: Grass clippings should be allowed to remain on the lawn following mowing unless excessive thatch build-up occurs. This will reduce the need for artificial nutrients. In addition, this will have a beneficial effect on the nationwide waste disposal problem, as bagged grass or leaves comprise 15-20% of all substances placed in landfills (Hugo, 1990). Raked leaves should not be disposed in or near the lake or its tributaries. Instead, they should be bagged and transported to a compost area away from any water flow path. If a compost area is used, runoff should not be allowed to reach the lake or tributaries.

<u>Trash Receptacles</u>: The number of trash cans and dumpsters should be sufficient to handle all trash deposited between collections. The containers should be cleaned with plain water directed from a spray nozzle. Disinfectants should be used sparingly and not allowed to drain onto the ground. Rinse water containing disinfectant must be properly disposed of.

Holes should not be drilled in the bottom of trash barrels to afford better drainage. Water percolating through these containers is high in nutrient and bacterial content, and should be avoided. Trash cans should be covered and not left open. Spring-loaded lids are recommended, and open topped drums should be avoided. Rusty receptacles should be replaced promptly. Trash cans should be placed as far as possible from the lake.

<u>Fertilizers and Chemicals</u>: Application of fertilizers should be avoided or minimized. These products will enhance the growth of algae and macrophytes in the lake if they are present in runoff. Application of other chemicals, such as pesticides and herbicides, should be carefully controlled and avoided if possible. Alternatives to chemical treatment should be investigated.

<u>Automobile Traffic</u>: The exhaust from internal combustion engines is high in metal, hydrocarbon, and nutrient content. So called "tailpipe drippings" are a major source of nutrients in urban watersheds. Drains and waterways along roads and parking lots should be situated so as not to channel runoff directly into the lake or its tributaries. Ideally, stormwater runoff should be routed to a treatment facility (or holding pond). If this is not feasible, runoff should be routed across large, vegetated areas prior to being allowed to enter the lake or its tributaries.

Education Centers: Visitors to Jellystone Park should be educated on issues surrounding the lake and its care. Broad-based nature exhibits or storyboards on specific problems, such as why fisherman should not clean their catch in or near the lake (entrails can lead to elevated bacteria counts and reduction in dissolved oxygen) would promote understanding of water quality issues.

5.3 IN-LAKE RESTORATION

The problems identified in Ridinger Lake stem from both nutrient enrichment and sedimentation. Although nutrients may be contributed as a result of near-shore activities, watershed inputs largely determine both in-lake nutrient concentrations and sedimentation rates in Ridinger Lake. As stated earlier, implementation of the BMP's previously described is considered the most effective strategy to restore the lake. The treatment of problems similar to those experienced in Ridinger Lake through in-lake techniques has been successful, however in most cases the lakes are deeper and have longer retention times (Cook et al., 1986). The relatively short retention time of Ridinger Lake (47 days) and moderately shallow depth suggest that the lake will respond rapidly to a reduction in external nutrient loading. Moreover, in-lake techniques, particularly those designed specifically to reduce nutrient concentrations, would be short-lived without corresponding measures in the watershed.

Recognizing that the Ridinger Lake Homeowners Association has little control over implementation of BMP's in the watershed, there are several in-lake techniques that would both increase lake depth and reduce nutrient levels, and at the same time enhance the effectiveness of watershed controls in improving water quality. Removal of accumulated sediment at the mouths of the three tributaries, artifical circulation, and weed harvesting are summarized below. These and other methods are presented in great detail in Cook et al., 1986, in a book entitled "Lake and Reservoir Management". The costs associated with all of these methods are significant. However, an improvement in water quality due to watershed BMP application is expected to be a gradual process that may take place over a period of several years. In the interim, in-lake restoration strategies represent the best options for immediate improvement in the condition of the lake.

5.3.1 Dredging

Dredging, or wet sediment removal, involves either scooping up bottom material in buckets that are subsequently emptied into a barge or truck for transport to a disposal area, or pumping the material as a slurry through a pipe to a constructed sedimentation basin for dewatering.

Bucket dredges consist of a dragline or backhoe operated from a barge platform, accompanied by a second barge to hold the dredge material. When the second barge is full, it is moved to shore where the dredge material is transferred to a truck for disposal. The advantages of this method include a high solids content of the dredge material, and a high degree of maneuverability of the dredge. Disadvantages include excessive turbidity at the dredge site and a relatively slow rate of removal.

Hydraulic dredges are the most common machines used in wet dredging operations. The dredge consists of a cutter head mounted on the end of a suction pipe suspended from a barge. As the cutter head dislodges sediment, the loosened material is sucked into the pipe in the form of a slurry. The slurry pipe extends from the barge to a disposal site, where a settling basin is required to dewater the material.

The advantages of hydraulic dredging include relatively high removal rates, high cost efficiencies, and minimum impact on the shoreline. Disadvantages include the need for containment basins, which often require several acres of land near the dredge site, relatively high turbidity, and the need for a suitable pipeline route from the lake to the dewatering basin. Maximum pumping distance with this technique is approximately one mile. Greater distance is possible, however in-line pumps are required which greatly increase the cost of the operation.

The bathymetric survey of Ridinger Lake found that approximately 63,000 yd^3 of sediment have accumulated at the mouths of the three tributaries to the lake since 1954. Taking the maximum of the \$2 to \$5 per cubic yard range of dredging costs reported in the literature, and assuming that all of this material would be removed, the cost of the dredging would be in the neighborhood of \$315,000 dollars. This estimate does not include costs associated with disposal or post-dredging monitoring.

5.3.2 Artificial Circulation

Artificial circulation is a lake restoration technique that is designed to eliminate thermal stratification and density barriers by increasing circulation within the lake. This results in oxygenation of bottom waters, improved fisheries habitat, and, in theory, a reduction in nutrient availability by oxidizing formerly anoxic lake sediments. Cowell (1987) evaluated this technique on a Florida lake using a multiple inversion aeration system. Significant reductions in turbidity, pH, alkalinity, total nitrogen, hydrogen sulfide, and iron were found in this study. Secchi disk transparency also increased significantly. This method has also been shown to control blue green algae blooms by shifting the algal community from blue-green dominated to the more desirable green algae dominated. Blue green algae are more bouyant, and thus have a competitive advantage over green algae during stratified conditions (Lorenzen, 1977). Rapid vertical mixing of the water column reduces this advantage. A marked reduction in blue green algae, and a 70% increase in the number of green algae species was demonstrated in the Florida lake mentioned above (Cowell, 1987). However, this was a soft water lake, and not directly comparable to the moderate to high alkalinities typical of midwestern lakes. A direct benefit to fisheries in terms of improved habitat quality, and extended habitat area would be the only result that could confidently be expected if such a system were installed in Ridinger Lake. Although some degree of reduction in internal nutrient release could be expected, the large watershed to lake area ratio would limit the effectiveness of such a system for this objective. Proper sizing of an aeration system, i.e., adequate air flow to completely destratify the lake, is critical to the success of this method.

In practice, an aeration system employs porous ceramic diffusers, similar to large scale aquarium air stones, or perforated plastic pipe to transfer pumped air from the surface to the lake bottom. Reaeration is accomplished through direct transfer within the water column, and, to a greater extent, by the forced movement of bottom waters to the lake surface. A commercially installed aeration system for Ridinger Lake may cost upwards of $120,000, however self installation of the pumps and other required equipment may reduce this by as much as 50%.

5.3.3 Weed Harvesting

The direct benefits of aquatic plant harvesting relate primarily to increased recreational use of the lake. However, nutrient removal and protection of the pelagic zone from nutrients released during macrophyte decay may also result from harvesting. If nutrient income is low to moderate and weed density is high, as much as 50 percent of the net annual phosphorus loading could be removed through intensive harvesting (USEPA, 1988). Mechanical weed harvesting, however, is energy and labor intensive. Additionally, plants may fragment and spread the infestation. It is recommended that floating barrier systems be utilized during harvesting to curtail the spread of buoyant plant fragments, and aid in their collection.

The objective of weed harvesting is to cut and remove nuisance growths of rooted aquatic plants and associated filamentous algae. The most common means of harvesting is accomplished through the use of a mechanical weed harvester; a maneuverable, low-draft barge designed with one horizontal and two vertical cutter bars, a conveyor to remove cut plants to a holding area on the machine, and another conveyor to rapidly unload plants. Harvesters vary in size and storage capacity, with cutting rates ranging from about 0.2 to 0.6 acres per hour depending on the size of the machine. Disposal of the cut materials is usually not a problem. Because aquatic plants are more than 90 percent water, their dry bulk is comparatively small. Additionally, farmers and lakeshore residents will often use the cut weeds as mulch and fertilizer.

Most harvesting operations are effective at producing a temporary relief from nuisance plants, and in removing organic matter and nutrients. In some cases, however, plant regrowth can be very rapid (days or weeks). Conyers and Cooke (1983) and Cooke and Carlson (1986) found that a slower method of lowering the cutter blade approximately one inch into the soft sediments would produce a season-long control of milfoil by tearing out the plant roots (USEPA, 1988). This harvesting method is only effective when sediments are soft and the length of the cutter bar (usually 5 - 6 ft.) can reach into the mud.

Harvesting costs in the Midwest range from $135 to $300 per acre (1987 dollars). Costs for a particular project, relate directly to machine cost, labor, fuel, insurance, disposal charges, and the amount of machinery downtime (USEPA, 1986).

SECTION 6. LONG-TERM MONITORING

A long-term water quality and sediment monitoring program would provide a basis for detecting changes in the water quality of Ridinger Lake. The objective of such a program would be to assess the condition of the lake, over time, and draw conclusions regarding future changes that may be observed. Additionally, if a decline in water quality should occur, and the causes are not immediately evident, the data collected under this program would provide the level of detail required for a professional lake manager to analyze the situation.

A monitoring program could be implemented for Ridinger Lake utilizing volunteers from both the Ridinger Lake Homeowners Association as well as land owners in the watershed. A similar volunteer program is currently underway at Shipshewana Lake in LaGrange County, Indiana. This section describes the basic components of a monitoring program that could be conducted by volunteers, with assistance from a local analytical laboratory. The program is described in two parts: data collection and data interpretation.

6.1 DATA COLLECTION

The core of the monitoring program would be the routine collection of water quality and sediment depth measurements. The collection of storm flow samples from the tributaries to the lake is also recommended, however, this would be a more difficult task given the unpredictability of sampling frequency.

6.1.1 Lake Water Quality

Water quality monitoring should include both in-situ measurements and laboratory analyses of water samples. In-lake measurements and samples should be collected from a single station at the deepest location in the lake. These measurements should be collected on a regular basis, such as the first Monday of each month, and at approximately the same time of day (i.e., early afternoon). In-situ measurements should include Secchi disk transparency, and temperature and dissolved oxygen profiles. The instrumentation required for these measurements may be purchased for between $850 and $1,000.

Water quality samples should be collected at the surface, mid-depth and approximately one foot above the bottom of the lake. Samples should be analyzed for total phosphorus, total nitrogen and chlorophyll a. A suitable Van Dorn-type water sampler may be purchased for approximately $400. Analytical costs will be dependent on the laboratory used. To minimize costs it is recommended that a local health department laboratory be utilized, if possible.

6.1.2 Tributary Storm Samples

Because sediment and nutrient loading is an issue of concern in Ridinger Lake, a basic program of tributary storm sampling is recommended. In sampling storm runoff there is a compromise between the ideal, which would involve flow-weighted samples collected throughout each storm hydrograph, and the practical constraints of limited funds to support the program. Flow-weighted sampling is very expensive, requiring sophisticated automatic monitoring and control packages, and substantial labor to maintain the equipment. In contrast, grab samples may be collected manually and only require some sort of sampling container. The disadvantage of grab samples is that they only represent a single moment in the storm hydrograph and pollutant concentrations are known to vary significantly throughout the duration of a storm. However, the consistent collection of many grab samples over a period of time can provide a basis for comparison among tributaries and detection of large changes in loading though time.

Collection of storm flow samples should be at, or just before the peak flow in each tributary. Storm samples should be analyzed for total suspended solids, total phosphorus and total nitrogen.

6.1.3 Sediment Accumulation

The results of this study indicate the Ridinger Lake is accumulating sediment adjacent to the mouths of Tributary #1 and Elder Ditch. Water depths in these two areas should be measured on a quarterly basis to monitor sediment accumulation.

Sediment monitoring stations should be established on transects running perpendicular to the shoreline and along the centerline of each of the two tributaries. Transects should extend into the lake several hundred feet, with stations spaced at approximately 50 foot intervals along each transect. Stations should be located using surveyor's instruments, such as an electronic distance measuring device (EDM), to allow the depth measurements to be taken at the same location each time. At each station, depth to the surface of the sediment should be measured using a surveyor's rod or similar calibrated pole. Lake surface elevation should be recorded for each round of station measurements to ensure that all measurements are referenced to a common horizontal datum. The Kosciusko County Surveyor may be able to assist the Ridinger Lake Homeowners Association in establishing the sediment monitoring program.

6.2 DATA MANAGEMENT

A single individual, or small group of individuals, should be responsible for all data collection and records maintenance to ensure that the monitoring is conducted reliably and consistently. Consistency of technique and analytical methods is essential to minimize random variability in the data and maximize the value of the collected information in detecting changes over time.

Standardized data forms should be developed and used for all field measurements and sample collection. The forms should be simple, but complete, and as easy to use in the field as possible. Both the in-situ data, and the results from the analytical laboratory should be entered into a PC-based database. There are numerous software packages available that provide the necessary features for ease of maintenance, statistical analyses, and graphics.

6.3 DATA INTERPRETATION

The monthly data generated by this program will provide a general characterization of Ridinger Lake. There are some simple methods for presenting the data that will allow local lake managers to utilize the data and draw some basic conclusions.

Graphic plots of the water quality and sediment data should be maintained as a basic interpretive tool. Water quality time-series data plots can be used to visually detect seasonal trends, long-term trends, and differences in extreme values between years. Fitting a simple linear regression through time-series data will often allow the detection of a long-term increase or decrease in a measured parameter (i.e., Secchi disk transparency or depth to sediment). Such a trend would be revealed by a regression slope that is statistically significantly different from zero.

Water quality parameters may be evaluated in terms of annual statistics. A simple example would be the examination of the average annual Secchi disk transparency along with the range of transparencies observed during the year. A trend of decreasing annual means and minimum transparencies would suggest that either suspended sediment or algae concentrations are increasing. Additionally, the Carlson trophic state index (TSI) could be applied to the monthly water quality data collected on the lake. A more representative trophic state assessment could be obtained by examination of the TSI values observed over a period of time. A good limnological text, such as Wetzel (1983) will provide more detailed interpretive guidance than can be provided within the scope of this investigation.

SECTION 7. SUMMARY

Based on the results of the watershed analyses, lake and tributary sampling, and visual observations, Ridinger Lake appears to be adversely impacted in the following ways:

- External nutrient loading, as evidenced by storm event tributary sampling and land use analysis, has created productive conditions in the lake, resulting in the dominance of blue-green algae, and deteriorating trophic conditions. This situation is expected to worsen until watershed controls (BMP's) are implemented.

- Total phosphorus levels in water samples collected near the lake bottom were very high, suggesting that internal release of nutrients from the anoxic lake sediments could be a major, secondary source of nutrient enrichment. The short residence time of the lake lessens the severity of this problem.

- Within the watershed, the Troy-Cedar Lake sub-basin contained the majority of "problem areas" identified using the Agricultural Non-Point Source Pollution model. However, lakes within this sub-basin act as barriers, intercepting both sediment and nutrients generated from the surrounding agricultural lands before they reach Ridinger Lake. Lands adjacent to the Troy-Cedar Branch upstream of Troy-Cedar Lake were identified as contributing disproportionately greater amounts of sediment and nutrients to Ridinger Lake via the Elder Ditch tributary system.

- Bacteria levels within the lake did not exceed Indiana Department of Environmental Management criteria for whole body contact. The coliform numbers were measurable however, and suggest potential contamination from septic systems and/or animal wastes from the watershed.

NO CHANGES FROM DRAFT

SECTION 8. RECOMMENDATIONS

The results of this study indicate that Ridinger Lake is experiencing moderate sedimentation and, to a greater extent, eutrophication problems. However, the degree of these impairments is generally not severe enough to warrant drastic restoration measures. Simple techniques such as weed harvesting are appropriate for improving conditions in the lake itself. A more extensive in-lake treatment technique, such as artificial circulation, is an option to the Ridinger Lake Homeowners Association for immediate improvement in lake water quality. If sufficient funds are available, this technique, and limited dredging of Elder Ditch and the northeast tributary, are the recommended in-lake restoration tools.

The primary thrust of long-term management efforts should be directed at control of sediment and nutrient production in the watershed. A general, integrated program for managing Ridinger Lake should include, in order of importance, application of: (1) upland best management practices (BMPs), (2) effective waste water treatment, and (3) limited in-lake restoration procedures. A brief outline of these management strategies is presented below:

1. Upland best management practices:

    a. Encourage the use of agricultural BMPs (e.g., conservation tillage, contour farming, buffer strips, animal waste management) in coordination with SCS and SWCD representatives.

    b. Implement effective erosion control strategies in residential areas and at construction sites.

    c. Enact and enforce appropriate zoning and development planning regulations for controlling the production of off-site pollutants.

    d. Encourage the use of appropriate grounds maintenance procedures to reduce nutrient inputs from Jellystone Park Campground.

2. Effective waste water treatment:

    a. Install septic systems in appropriate soil-types, with adequate distance buffers between leach fields and lake/tributary systems.

    b. Ensure adequate capacity for peak use periods and implement proper maintenance routines (e.g., yearly inspection, periodic pump-out in the short term and relocation/reinstallation in the long term).

3. In-lake techniques:

   a. Harvest aquatic weeds that are causing navigational and recreational problems on an as-needed basis. Do not attempt to completely eradicate aquatic plants as they provide fisheries habitat and also act as a filtering device at tributary entrances.

   b. Consider the use of artificial circulation to improve fisheries habitat, and potentially reduce internal nutrient loading.

   c. Increase the depth of the lake at the mouths of Tributary #1 and Elder Ditch through sediment removal.

   d. Use physical/chemical treatment methods as noted by IDEM (1986) sparingly. These methods should be targeted at changing nutrient availability to aquatic plants; removing the nutrients from the photic zone; or preventing the release/recycle of nutrients from the sediments.

For Indiana DNR Lake Enhancement Projects, Design Studies are conducted to implement recommendations of the Feasibility Study, and provide sufficient detail to allow contractors to bid competitively for construction of restoration measures. At this time, a Design Study for Ridinger Lake is not recommended for the following reasons:

- The overriding problems are watershed inputs of sediments and nutrients. A study conducted by the U.S. Soil Conservation Service in the northern Tippecanoe Drainage Basin is currently underway. This five year study, begun in the spring of 1990, is aimed at accelerating BMP implementation in this basin, which includes the Ridinger Lake watershed. Data from the Ridinger Lake Feasibility Study will help target the efforts of this project, further decreasing the amount of time required for watershed controls to improve water quality in the lake.

- The Ridinger Lake Feasibility Study contains information sufficient to develop detailed requests from qualified contractors for in-lake restoration measures. While more in-depth monitoring and further evaluation of in-lake control strategies would be beneficial, IS&T does not feel that the costs associated with additional monitoring would be warranted. An existing program of maintenance dredging for Elder Ditch is already in effect. The bathymetric data in this report could be used to estimate the costs of dredging the northeast tributary to the lake as well as Elder Ditch. The Ridinger Lake Homeowners Association should consult with the Koskiusco County Surveyor, District Conservationists in Koskiusco and Whitley Counties, and the Lake Enhancement Program office regarding financial assistance for in-lake restoration.

- The lake watershed land treatment program, a new element of the Lake Enhancement Program, is an avenue through which funding may be pursued for implementation of upland best management practices. This program provides cost-sharing assistance to landusers for application of agricultural management practices designed to reduce the input of sediment and nutrients to a project lake. The Ridinger Lake Homeowners Association is encouraged to consult with the Kosciusko and Whitley Counties Soil and Water Conservation District representative and SCS District Conservationists, and the Lake Enhancement Program office regarding financial assistance through this program.

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